IS A TURRETLESS TANK A VIABLE OPTION FOR THE UNITED STATES ARMY

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

GARY L. MOORE, MAJ, USA
B.S., University of Tennessee-Chattanooga, 1976

Fort Leavenworth, Kansas
1990

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1 June 1990	Master's Thesis, Aug 1989 to Jun 1990

4. TITLE AND SUBTITLE
Is A Turretless Tank A Viable Option For The United States Army

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Command and General Staff College
Attn: ATZL-SWD-GD
Fort Leavenworth, KS 66027-6900

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*

This study is an examination of four areas, historical U.S. tank development, U.S. national military strategy, Army doctrine, and technical design considerations, that have had an impact on the design of U.S. Army tanks. The aim of this study is to identify the influences each of the aforementioned categories have had on the design of U.S. Army tanks, the implications these offer for the design of future tanks and from these ascertain the viability of a turretless tank as a developmental option of the U.S. Army. This study concludes that a turretless tank is a viable option for the Army to pursue.

14. SUBJECT TERMS
Tank Design, Armored Vehicle Design, Turrettless Tank, U.S. Tank History AirLand Battle Doctrine, U.S. National Military Strategy

15. NUMBER OF PAGES
177

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

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Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

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Block 16. Price Code. Enter appropriate price code *(NTIS only)*.

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

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1990

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The opinions and conclusions expressed herein are those of the student author and do no necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

IS A TURRETLESS TANK A VIABLE OPTION FOR THE UNITED STATES ARMY: An examination of the factors that have influenced Army tank design and use of those factors to determine if a turretless design is a viable option for future Army tanks by Major Gary L. Moore, USA, 177 pages.

This ~~study~~ is an examination of four areas, historical U.S. tank development, U.S. national military strategy, Army doctrine, and technical design considerations, that have had an impact on the design of U.S. Army tanks. The aim of this study is to identify the influences each of the aforementioned categories have had on the design of U.S. Army tanks, the implications these offer for the design of future tanks and from these ascertain the viability of a turretless tank as a developmental option for the U.S. Army. The impacts of U.S. tank design were gleaned from historical writings on the development of U.S. tanks, a large body of literature on tank technical design considerations, official U.S. government statements of the national military strategy and Army doctrinal warfighting manuals. Analysis by the author of the above impacts were considered in the context of the current national and international situations.

This study concludes that a turretless tank is a viable option for the Army to pursue. A turretless tank provides significant potential benefit in the reduction of tank cost and weight. Additionally, reduced size leads to improved survivability. The Army's challenge is to continue to defend global U.S. interests in an era of reduced military spending. Development and fielding of a turretless tank is one of the ways the Army can meet this challenge.

ACKNOWLEDGMENTS

Writing this thesis has been a major task which was made possible with the assistance of many individuals. I want to express my sincere appreciation to some of those who have materially assisted me in this research project.

First, I want to thank my family, Marie, Clinton, Andrew and Scott, for their support. The time I could have spent with them, was consumed at a keyboard or buried in research. Without their support and understanding, this thesis would not have been completed.

Second, I would like to extend my appreciation to the members of my research committee, Mr. James F. Fox, Mr. Dwain H. Skelton, and COL Fred Dellva. They took considerable time out of already busy schedules to read, provide guidance and encourage me to the completion of this project. Their expertise in the combat developments process has proven invaluable. Additionally, I would like to thank LTC Don Baker. Although duty requirements prohibited his offical membership on the thesis committee, his assistance was invaluable.

Next, I would like to thank the members of my A021, Research Methdology II, seminar group. The group, lead by LTC Michael F. Keohane, provided valuable insights into how to do it better. The encouragement they provided in the grey days of winter was instrumental for my staying the course. An especially helpful member of the group and personal friend is MAJ Bill Klenke. Bill provided an extremely helpful objective review of, and structural suggestions for, this thesis.

Finally, Dr. Philip Brookes and the staff of the Graduate Degree Programs office have been extremely helpful for a novice graduate student. Their willingness to answer even the most mundane question combined with an always cheerful attitude have been a foundation for my efforts.

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CHAPTER 1

DEFINING THE PROBLEM

INTRODUCTION

The purpose of this study is twofold. The first is to research the major factors that influence United States Army tank design and development. The aim is to identify implications for future tank development. The second is to analyze these implications to determine the viability of a turretless tank design as a fielding option for the Army.

Four factors have, and will, play a role in determining the design of U.S. Army tanks. Historical considerations, including past efforts of the Army's tank design and development program, is the first factor examined. Identification of historical trends in the Army's tank program will assist future tank program personnel to avoid past errors. A second factor is the U.S. national military strategy. This strategy identifies the requirements for the Army and hence its materiel needs. The third area of investigation is the Army's warfighting doctrine, AirLand Battle. AirLand Battle (ALB) is the Army's method for carrying out its missions in the national strategy. This doctrine is the basis for materiel design and acquisition in the Army and sets the requirements for what a future tank must do on the battlefield. The fourth factor is the technical design factors considered in tank design. These technical factors proscribe the limits, or bounds, into which a design will fall. The implications, or design requirements, identified in the review of these four areas are essential in analyzing the suitability of a turretless tank design for the Army.

Turrets first appeared on French tanks in World War I and have dominated design since. A turret serves two primary functions. First, it gives the gun the ability to move, or be directed toward targets, without requiring the movement of the entire vehicle. Secondly, the armored turret provides protection for the gun, and the crew that services it, from the effects of enemy fires. Turrets provide such additional benefits as: protected stowage for ammunition and increased height which increases crew observation of the battlefield.

There are also disadvantages inherent in the use of a turret on a tank. The additional height of the turret above the hull, while providing greater observation, also increases the vehicle's visual signature making it more difficult to hide. Up to 30% of a tank's weight is in its turret. The effect on total vehicle weight of armoring the turret is significant.

Weight is the most crucial factor in a tank's design. Weight determines the vehicle's tactical and operational mobility, its ability to move about the battlefield. Strategically a tank's deployability relies on the capabilities of air and sealift assets. As tank weight increases, the lift assets available to move it to potential combat zones around the world decrease.

A turretless tank may offer solutions to the disadvantages of turreted designs. A turretless tank's primary characteristic is the location of the crew in the hull of the vehicle. There is a reduced or no armored compartment above the hull. The tank's primary weapon, the cannon, is mounted externally or in hull. The Swedish S Tank is an example of in hull design. Such a design has the disadvantage of a lack of independent gun movement. The whole vehicle has to be turned or elevated to point the gun at its target.

In one turretless design option, an unarmored or lightly armored articulated gun is externally mounted above the hull. Unlike a turreted design though, there are no crewmembers located above the hull with the gun. Without a need to protect the crew outside of the already heavily armored hull, the volume, size and weight of the externally gunned vehicle is significantly reduced. Advantages are therefore gained in vehicle weight and signature. Such an arrangement, however, relies on advanced technological components. An autoloader and optronics that allow the crew-in-hull to see the battlefield are examples.

A turretless tank is a radical departure from traditional turreted designs and requires the incorporation of emerging technologies. Turreted tanks are approaching the limits of historical design criteria. Continuing in this traditional turreted design vein will impose restrictions on the strategic, operational and tactical capabilities of future tanks. It is therefore imperative that senior Army leaders objectively consider U.S. tank requirements. Consideration of the impacts of these requirements on design is paramount when determining the direction of the U.S. tank program for the future.

BACKGROUND

In World War II, the tank emerged as a significant force on the modern battlefield. Since then, the tank has become the centerpiece of land forces. Generalleutnant Dr F.M. Von Senger und Etterlin, one of the architects of Germany's World War II panzer armies, remarked in 1978 that "The...tank remains the decisive weapon system of modern armies at tactical and operational levels."[1] The acceptance of this view is evident in the composition of the Soviet, U.S. and many other armies around the world.

Tanks have been key to Army forces since World War II. This emphasis on armor has been a result of the prevalent threats to U.S. national security. In World War II the

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[1]Richard Simpkin, Tank Warfare (1979): 11

armored formations of Nazi Germany were the primary threat. Since the late 1940s, the massed tank and armored units of the Soviet Union in Central Europe have been the U.S.'s most dangerous threat.

U.S. national strategy since World War II has focused on the Soviet threat. This focus has resulted in an evolving military strategy that now espouses the tenets of forward defense, coalition warfare and flexible response. The US Army's current warfighting doctrine, AirLand Battle, is derived from, and supports the national military strategy.

AirLand Battle (ALB) doctrine is a result of the requirement to defeat the massed armored echelons of the Soviet Army. ALB not only applies to heavy forces fighting in Europe, but also guides Army operations in mid and low intensity conflicts worldwide. As the foundation for materiel acquisition, ALB has guided the Army through the unprecedented peacetime modernization of the 1980's.

ALB doctrine is evolving with current efforts to define the Army's warfighting concepts for the 1990's and beyond. The AirLand Battle-Future Nonlinear (ALB-FN) concept seeks to define how the Army will fight with a force structure that has been changed by current political and budgetary considerations. Critical to the ability of ALB-FN techniques to ensure victory on a future battlefield are the tactical and operational capabilities offered by the tank.

Facing the Army in the 1990's is a decade of enormous change. Old enemies (i.e., the Soviet Union) are becoming, in fact or perceived, less threatening and U.S. interests are increasingly global. This increased span of interest offers the potential for combat in many areas of the world. Considering that more than a dozen developing countries each have more than 1,000 main battle tanks, the Army's requirements for tanks will not diminish.[2]

Correspondingly, changes in the focus of national military strategy will require a review of the Army's missions. Changes resulting from such a review will impact it's doctrine, training, organization and materiel requirements. Budget limits imposed by the Department of Defense, the President and Congress will constrain the ability to satisfy these requirements.

Budget limitations on defense spending will become increasingly more constraining. The search for ways to reduce the US national debt by the legislative and executive branches will lead to defense cuts. Reductions in the deficit, hence budget reductions, will be expected by an American public that foresees the realization of a "peace dividend." The perceived reduction in the external threat to U.S. national security is the source of such a dividend. This perception is not unexpected with the outbreak of

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[2]Carl E. Vuono, General, US Army, "The United States Army Is a Strategic Force," Armed Forces Journal International (February 1989): 61

freedom and democracy in Eastern Europe and unrest in the Soviet Union. In fact, the proposed 1991-95 Department of Defense budget, originally considered worst case is now viewed as optimistic. The proposed budget calls for an annual two percent decrease in each of those years, for a total 160 billion dollar budget reduction.[3] It is, therefore, incumbent on the Army to realize significant return on its investment of limited dollars in developing the Army of the future.

Budget reductions will impact the Army in both materiel and force structure. Besides the obvious need to minimize materiel procurement costs, Operations and Sustainment (O&S) costs also must be reduced. O & S costs, the cost to operate materiel, includes petroleum, oil, lubricants (POL), repair parts and manpower costs. These costs must be minimized both for peace and wartime operations. This reduction in O & S can be achieved through application of technologically advanced systems and components that ease manpower requirements and lower operating costs.

Force structure, the number of personnel spaces supported by the budget, will also be affected. In a five year, 160 billion dollar budget reduction, DOD would need to cut approximately 290,000 service personnel from the

[3] "White House to seek cuts of 2% a year for defense," The Kansas City Times (January 6, 1990): A, 3a-c

rolls.[4] If spread equitably, the Army would experience manpower reductions approximating 100,000 personnel. It is conceiveable that an Army of 500,000 soldiers may be in the future.

A solution to these problems may be the turretless tank. A turretless tank, a break from traditional turreted designs, could reduce both O & S and manpower impacts in several ways. First, the incorporation of advanced technological systems and components could significantly reduce life cycle costs versus the costs of traditional designs. These advancements in technology would provide the additional benefit of reducing the requirement for the number of tank crewmembers, from the current four, to three or less. Such a reduction would accrue a significant manpower savings across the force. With the elimination of the fourth crewman and turret, a reduction in size and weight would be possible. Size and weight are key considerations in deployability requirements.

Strategically, materiel must be rapidly deployable and employable in any theater required. The plains of Central Europe, the deserts of South West Asia and the jungles of Latin America are potential theaters of combat for the Army. The December 1989 U.S. invasion of Panama is evidence that U.S. armed forces will be deployed on short notice to protect U.S. interests. As the soldiers and equip-

[4] Kansas City Star, (January 6, 1990): A, 3a-c.

ment of the 82d Airborne Division and 7th Infantry Division (Light) are rapidly deployable, so must be, to some extent, the heavier materiel of war such as tanks. At weights approaching seventy tons, the M1 is not rapidly deployable. This heavy materiel, and the units that employ it, provide the staying power necessary for sustained combat against more substantial forces that are like equipped.

The Army is indeed faced with a decade of challenge. How to best meet the requirements of national strategy in an era of change when reduced military spending will be the norm is the Army's challenge. A turretless design for the next generation of Army tanks would appear to be a way to meet the challenge.

ASSUMPTIONS

By the year 2000, armor technology will not have advanced to a degree that offers a weight saving capability and still meets U.S. tank requirements within traditional turreted designs.

There will be a requirement for a follow-on to the M1A2. Armaments development is most often evolutionary. As technology matures and threats change, the M1A2 will become obsolete, unable to perform the missions for which it was designed. As this occurs, the requirement for a more advanced tank design will result in a new MBT for the Army.

Threat technology will continue to demonstrate improved survivability over the next 10-15 years. Consequently, improved tank cannon lethality will be required. Lethality enhancement may result in larger, heavier cannons, adding even more weight to the vehicle.

U.S. defense budgets will continue to decline. This decline will be forced by an urgent need to reduce the U.S. budget deficit and the public perception that the threat to U.S. national security is diminishing.

U.S. national military strategy will change in the period from now to the year 2000. This change in strategy will be motivated by the popular view that the threat has abated. It will probably be reflected by reductions in the number of forward deployed U.S. ground forces. Reducing forward deployed forces additionally offers a chance to recoup some of the expensive costs of such stationing.

Army doctrine will not change significantly in the period from now to the year 2000. Changes will be evolutionary adjustments to current doctrine.

The available pool of service age manpower will decline. The societal trend to smaller, later families and the demographics of the post baby boom generation will de crease the numbers of teenage males available for service.

DEFINITIONS

Viability: Having a reasonable chance for acceptance by the Army for development. It is based on the Army's requirements, the associated cost considerations (research and development, initial purchase and operations and sustainment costs (life cycle costs)), the projected rate of associated technological development and political considerations.

Requirements: The operational characteristics defined as necessary for a main battle tank to meet Army missions as stated in a Required Operational Capability (ROC).

Doctrine: As stated in Field Manual 100-5, Operations, doctrine is defined as: "how Army forces plan and conduct campaigns, major operations, battles, and engagements in conjunction with other services and allied forces. It is the authoritative foundation for subordinate doctrine, force design, materiel acquisition...presents a stable body of operational and tactical principles rooted in actual military experience...." Training and Doctrine Command (TRADOC) Pamphlet 34-1, "Doctrinal Terms" defines doctrine as: "Fundamental principles by which military forces or elements thereof guide their actions in support of national objectives. It is authoritative but requires judgment in application."

US national military strategy. The National Command Authority's (NCA) guidelines for employing the military element of national power in support of achieving national interests and objectives.

LIMITATIONS

Classification. This thesis will be written at the unclassified level to encourage widest possible dissemination. Research has been conducted in open sources. Classification also restricts the research of some technological advances which are beyond the clearance levels held by the author.

DELIMITATIONS

Historical review and analysis will only consider U.S. tank design from 1919 to the present M1A2. After the end of World War I the United States retreated behind the barriers of its oceanic fortress. Isolated from international tank development, independent U.S. thought and design influence was applied toward tanks. Even though several other countries developed advanced tank designs, their impact was not examined except where it may have had a direct influence on U.S. tank design or doctrine.

National military strategy review is limited to official statements by the NCA of US national security strategy. As can be imagined, almost everyone has an opinion on what should be the security strategy of the US. Any attempt to consider the opinions or official positions of non NCA agencies would lead to a multitude of varying scenarios with a resultant divergence of implications for tank design.

Doctrinal review will consider the Army's current doctrine, AirLand Battle, as stated in FM 100-5, Operations, dated May 1986. Evolving concepts such as AirLand Battle-Future (ALB-F) Nonlinear will not be examined due to their draft and often changing status.

SIGNIFICANCE OF THE STUDY

The author hopes that the results of this study will weigh-in to the debate on development of future tank designs. It is also desired that this will contribute to the body of knowledge that senior decisionmakers, both in and out of the Army, will consult when making future tank program decisions.

This thesis links historical tank development trends to the strategic and doctrinal requirements imposed on Army materiel design efforts. These implications are further examined within the context of technical design criteria and used to determine the usefulness and acceptability of a turretless design.

Any major materiel acquisition program merits careful consideration before embarking on a development effort.

This concern is magnified with anticipation of a radical change from the norm. The intent of this paper is to ensure consideration of historical, strategic and doctrinal implications in the evaluation of an alternative design that may offer significant capability enhancement.

METHODOLOGY

The research methodologies used in this thesis are a descriptive archival and a quantitative analytic method. The descriptive archival method is pertinent to the identification of tank design considerations in the four areas of investigation; historical, technical design, national strategy and Army doctrine.

Historical research is primarily of secondary sources that cover the period under investigation. These sources offer the advantage of having done analysis of the events and provide insights, lessons learned or implications for future tank design.

Research of the technical design area is predominately from primary sources. A significant body of literature exists on tank design by some of the worlds foremost experts in this arena. Technical design is particularly dynamic with a current vigorous debate in professional publications over tank design of the future.

Investigation of the national military strategy and Army doctrine is limited to the primary official publications of the U.S. government and the Army.

Considerations for tank design are gathered from the review of each of the above areas. These considerations are used as criteria to comparatively evaluate two design alternatives, one a turreted tank, the other a turretless design. The comparative evaluation is conducted by applying the design considerations and alternative designs to a simple decision matrix. The author's subjective evaluation and scoring of the design alternatives capability in each of the design considerations yields a total score for each option. This score is then used to compare the alternatives. To facilitate the identification of design considerations and analysis this thesis is structured as follows:

CHAPTER 1 - DEFINING THE PROBLEM

This chapter introduces the subject within the framework of the research questions, provides a background that focuses the need for the thesis and provides boundaries for the study by enumerating assumptions, definitions, and limitations. The chapter concludes with an explanation of the study's significance and the research methodology that is used.

CHAPTER 2 - SURVEY OF LITERATURE

This chapter provides the reader a brief review of the key sources of information used in the research. The chapter is subdivided into four parts, historical, technical design, strategy and doctrine. Each part addresses the literature pertinent to that area.

CHAPTER 3 - HISTORY OF AMERICAN TANK DESIGN

Chapter 3 reviews the history of the U.S. tank program, how we got to where we are today. The three subdivisions of the chapter parallel the identifiable periods in American tank development, the Inter-War Period, Post World War II, and the era of the New Tank. Implications and lessons learned from development and combat experience are summarized.

CHAPTER 4 - STRATEGIC AND DOCTRINAL CONSIDERATIONS

Chapter 4 reviews current U.S. national military strategy, and the Army's AirLand Battle doctrine. Strategy and doctrine determine the requirements for Army modernization in the domains of training, leader development, organizations and equipments. It is necessary to understand the demands made by national strategy and Army doctrine to evaluate a turretless tank design. Included at the beginning of this chapter is a brief synopsis of the Army's materiel acquisition system.

CHAPTER 5 - TECHNICAL DESIGN CONSIDERATIONS

Chapter 5 examines the primary characteristics of a tank and the technical design factors contained in each. Survivability, mobility and lethality have been the key components to tank design since the introduction of the tank in World War I. Knowledge of the design considerations comprising these three characteristics will aid in the evaluation of the turretless tank conducted in Chapter 7. Chapter 5 concludes with a review of the cost considerations of personnel and money in the context of current defense budget reductions. Personnel and monetary limitations imposed by the Congress set the bounds within which future design must fall.

CHAPTER 6 - ALTERNATIVE TANK DESIGNS

In this chapter the base case tank for the comparative analysis is described. Then, using the data gathered in previous chapters, the author constructs two hypothetical designs for comparison. The first is a turretless tank. The second design is a conventional turreted design. These designs, base, turreted and turretless, are used as the basis for comparison in the analysis conducted in Chapter 7.

CHAPTER 7 - ANALYSIS AND DISCUSSION

In this chapter the analysis is conducted. The author's subjective evaluation of the capabilities of the three designs in each of the areas of design consideration is undertaken. Discussion focuses on the rationale for the scores provided in the decision matrix.

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis conducted in Chapter 7, the answer to the research question, the conclusion of this thesis, is provided. Topics for further research are provided as recommendations to future researchers. These topics were generated by the author's identifcation of gaps in available knowledge that are pertinent to consideration of turretless tank design.

SUMMARY

This chapter has explained the purpose of the study and identified the four areas of investigation. The introduction also explains the differences in turreted and turretless designs. The factors that motivate an investigation of a turretless design have been examined in the background section. Additionally, the boundaries of the study have been defined, significance stated, the research methodology identified and the structure for the thesis presented. Evolving tank design has resulted in an American Main Battle Tank that approaches seventy tons in weight. The penalties imposed by this high weight are exacerbated by drastically changing international and domestic situations. A turretless tank design offers the potential to provide the Army with a capability to meet the challenges of the future.

CHAPTER 2

SURVEY OF LITERATURE

INTRODUCTION

A survey of literature is provided to acquaint the reader with the sources of information utilized in this study. The survey provides future researchers a summary of the information available in the four areas of study in this thesis. The four areas under study are: historical U.S. tank development, technical design factors, military strategy and Army doctrine.

The primary source of research material was the Combined Arms Research Library (CARL) at Fort Leavenworth, Kansas. This source was supplemented with instructional material presented to the Command and General Staff College (CGSC) class of 1989-90. Additionally, the Combined Arms Combat Developments Activity (CACDA) provided information pertaining to current or ongoing Army concepts. Commercially available news sources were also used to gain an insight into current events that may shape the tank of the future.

A majority of the research material used can be divided into two categories, books and periodicals. Books provided an excellent in-depth review of areas under study.

Periodicals gave further insights into current trends, as in tank design, or a different viewpoint in historical analysis. Additional material such as government pamphlets or Army field manuals have supplied official statements of policy.

This chapter is divided into four parts addressing the four areas of study. Each part summarizes the key research material pertinent to that area. Except where noted, source material is unclassified.

PART I

HISTORICAL

A significant amount of literature is available on the history of tanks. The most generous portion is devoted to the world wide history of tank design, development and employment. Following is a brief summary of sources.

BOOKS

Armour In Conflict by Ian V. Hogg provides a survey of the international development of tanks and the battlefield results of these development efforts from the employment of the first tanks in World War I to the October War of 1973. Hogg rounds out this comprehensive effort with insights into specific design considerations such as suspension, ammunition, etc.

Orr Kelly's endeavor, King of the Killing Zone, is a very helpful review of the development of the Army's current main battle tank, the M1 Abrams. Kelly provides a brief look at the history of tank development but focuses specifically on the M1 program. Key political and budgetary factors, and the combat experiences of program personnel are examined, the total of which resulted in the development of the Abrams. Kelly's review begins with the aborted joint American-German MBT-70 effort of the early seventies. Review of the U.S. XM-803 program which leads to the M1 follows. This history concludes with examination of the impacts from fielding of the final product and it's variants. Throughout he provides excellent insights into the Army's latest tank development program. The book provides excellent insights into how the Army develops materiel.

Tank Warfare, by Brigader Richard E. Simpkin, Royal Armoured Corps, provides a brief look at the history of tank warfare and the lessons learned by NATO and the Soviet Union.

R.P. Hunnicutt's series of works provides a detailed review of the American tank program from World War I to the present. Firepower: A History of the American Heavy Tank, Sherman: A History of the Medium Tank, and Patton: A History of the Main Battle Tank provide a comprehensive look at U.S. tank design efforts.

Tank versus Tank, by Major Kenneth Macksy, Royal Tank Regiment, explains tactics, strategy, and the international development of both. Also presented is information on the employment of tanks versus other tanks. This effort is set against the background of technical advancements and the growing threats from field artillery, mines, aircraft and anti-tank missiles.

Armoured Forces: A History of Armoured Forces and their Vehicles by R.M. Ogorkiewicz is an excellent commentary on the development of the tank forces of several different countries. Ogorkiewicz reviews vehicle design evolution in each country. A following section analyzes the development of tank doctrine and its subsequent impact on design. This is a well written, thorough book which anyone interested in the world wide history of tanks should consult. This book was especially benefical in compiling the historical section of this thesis.

Captain Jonathan M. House's research survey, Toward Combined Arms Warfare: A Survey of 20th-Century Tactics, Doctrine, and Organization is a comprehensive effort that reviews the evolution of tactics, doctrine and the force structure organizations of the key 20th century world powers. The section devoted to U.S. efforts was very helpful in examining historical tank development.

Lieutenant Colonel Ken Steadman's pamphlet, The Evolution of the Tank in the U.S. Army, 1919-1940, provides a background of World War I influences on U.S. thought. Examined are the political climate of the Army during the inter-war period and the formulation of the doctrinal basis for U.S. tank employment in World War II. This pamphlet proved benefical identifying the many factors at work during the critical Inter-War period of U.S. tank development.

Lessons Learned from 20th Century Tank Warfare: Does A Common Thread of Lessons Exist?, Major Matthew L. Smith's MMAS thesis, provides a succinct review of lessons learned from key armor battles of the 20th Century and their design impacts in the five areas of mobility, firepower, protection, command and control, and overall vehicle design.

PERIODICALS

Dr. Christopher R. Gabel's article, "Evolution of U.S. Armor Mobility" recounts the pre-World War II debate in the Army of the size and type tank required. This debate was generated by the lack of a clear Army doctrine for tanks, with impacts on the armored force fielded in World War II.

"The 10 Lean Years," a posthumous series of articles by Major General Robert Grow was published in Armor Magazine. MG Grow recalls the Army's quest for mechanization in the inter-war period from a cavalryman's perspective. His account provides an excellent insight into the forces that shaped U.S. tank development in the late 1930s.

PART II

TECHNICAL DESIGN

BOOKS

Few books are available on the subject of tank design, however the two discussed below are particularly helpful in explaining the complicated interrelationships of tank design. The majority of technical design literature appears in periodicals and reflects innovative, and sometimes controversial thought on the subject.

Simpkin's Tank Warfare, devotes two-thirds of it's content to technical design criteria, their interrelationship and the implications for NATO. Simpkin additionally addresses *human engineering* factors in tank design, or as it is known in the Army, MANPRINT considerations. This is an excellent book by one of the world's foremost experts in tank design. Simpkin's use of a "design triangle" proved extremely helpful in understanding the complexity of tank design.

Armoured Forces, by Ogorkiewicz, addresses armored vehicle design from the aspect of a design program and the many considerations involved therein. The book also includes a look at the design considerations of several different types of armored vehicles such as self-propelled guns, armored cars and amphibious vehicles.

PERIODICALS

"Elements of Tank Design," by Gerald A Halbert, reviews the basic factors of tank design such as length-to-width ratio, ground pressures, width and height. Halbert relates the impacts of one on the other and provides examples in international tank development.

Robin Fletcher's "Creating the Turretless Tank" surveys current turretless tank designs and the problems posed by each. Fletcher analyzes these problems and proposes solutions.

"How Should a Tank Be?" by Red Army Colonel O. Ivanov reviews evolving international tank designs from a Soviet perspective, and forecasts design trends for the tanks of the future.

C. N. Donnelly's review of Soviet doctrine in "The Development of Soviet Doctrine" provides an insight into the impacts that doctrine has had on the development of Soviet materiel and equipment.

One of the most helpful articles was Craig Koerner and Michael O'Conner's work "The Heavily Armored, Gun Armed Main Battle Tank is Not Optimized for Mechanized Warfare." Their discussion of the impacts of adding armor to gain protection and the inexpensive nature of countermeasures to combat the additional armor were thought provoking. Especially interesting was the discussion of the effects of vehicle weight on tactics.

Richard Simpkin in "Room at the Top," discusses how modern battlefield weaponary and increasing weight are working to make the conventional turreted tank obsolete. Simpkin then identifies the requirements necessary for a workable turretless tank followed by four proposed turretless design options. This article is an excellent summary of possible turretless design options.

"The Two Man Tank" by Linwood Blackburn provides an excellent summary of the disadvantages of increasingly heavy turreted tanks. His discussion of the advantages offered by a lighter, two man tank, and the impacts of these advantages on the Army provided additional avenues for research.

"The Search for Safer Combat Vehicles: How Close Are We Getting" by Donald R. Kennedy addresses the critical issue of crew survivability. Kennedy reviews the historical problems in this area and proposes specific solutions. This is a good article that everyone involved in tank design should read.

PART III

NATIONAL MILITARY STRATEGY

BOOKS

The base documents of National Military Strategy and Army doctrine are official publications that provide the political administration's policy and the approved Army doctrine. Other publications, books and periodicals, provide the individual author's interpretation and views of the official policy. To avoid author influence, review of strategy and doctrine is limited to these official statements of government policy.

National Security Strategy of the United States issued by The White House in January 1988, is a concise explanation of the values and interests of the United States government. This listing of interests leads to discussion of the security policy of the country and lays down a framework for the national military strategy.

The Annual Report to Congress: Frank C. Carlucci, Secretary of Defense; Fiscal Year 1990 provides a detailed description of the national military strategy. Included is an examination of the impacts and requirements of that strategy in the different regions of the world. The report also provides an assessment of the threat to U.S. national security in each area.

PERIODICALS

The current upheaval in Eastern Europe and the Soviet Union potentially have far reaching impacts on U.S. military strategy. Such cornerstones of strategy as forward defense and coalition warfare will be affected. Newspapers and news magazines provide an excellent medium to remain abreast of presidential and congressional actions that will affect the national military strategy.

PART IV

U.S. ARMY DOCTRINE

BOOKS

FM 100-5, Operations is the Army's capstone warfighting doctrinal manual. This manual prescribes how Army forces plan and conduct campaigns, major operations, battles and engagements. The manual furnishes the authoritative foundation for subordinate doctrine, force design, materiel acquisition, professional education and unit and individual training. It is commonly known as AirLand Battle (ALB) doctrine. ALB pervades all other Army warfighting manuals.

AirLand Battle-Future (ALB-F) is a concept for fighting the Army in the 21st Century. It is an effort by the Combined Arms Combat Developments Activity, Fort Leavenworth, Kansas, to determine the viability of ALB in the next century. Where past interest has been heavily influenced by the Army's European mission, ALB-F recognizes that Army requirements are truly global in nature and will require an array of force mixes to meet all requirements.[1] Changes to the bedrock of ALB are minor but evolutionary. This concept paper is classified For Official Use Only.

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[1]U.S. Army, "AirLand Battle Future White Paper Draft," Combined Arms Combat Developments Activity (5 February 1990): 1-1

The recently emerging AirLand Battle Future Nonlinear concept is an effort to integrate the factors of change into a viable doctrine. These elements of change are exemplified by budget restraints, a changing threat and arms control agreements. The draft statement of this concept is contained in the Combined Arms Combat Developments Activity white paper entitled "AirLand Battle Future Alternate Base Case Study, Phase I, 2 February 1990." This concept is presently in the draft stage in the process of refinement.

SUMMARY

This chapter provides the reader a review of the significant literature the author has used in his research. It is by no means an exhaustive listing of all sources utilized, the bibliography should be consulted for such a list. The sections contained in this chapter reflect the four areas of investigation: American tank program history, the national military strategy, technical design criteria and Army doctrine. Each section contains a brief review of the key source material pertinent to that area.

The most helpful source for the author was Simpkin's Tank Warfare. The detailed explanation of the very complex aspects of tank design ensured understanding by even the novice. His review of where tank design is, and possible courses for future development is well worth reading for any armor crewman.

The numerous sources on tank history provide the researcher with as much detail as he is willing to consume. Tank doctrinal development, force structure design and historical technical design considerations are all covered in a plethora of sources.

Historical and technical design literature provide comprehensive, worldwide examination of tank development. However, little open source information on specific future American tank design considerations exists. This thesis attempts to fill that void.

CHAPTER 3

HISTORY OF AMERICAN TANK DESIGN

INTRODUCTION

This chapter discusses historical U.S. tank design and development beginning in 1919 through the design of the Army's current MBT, the M1A1. The factors that influenced design, doctrine, budget, etc., and the resultant products are examined to gain a fuller understanding of American tank design history.

This chapter will not attempt to review every experimental design the Army pursued. Such a comprehensive look is beyond the scope of this paper. Instead, an examination is undertaken of the major designs that were produced. These production models incorporated the best features of various design efforts.

Tank development, in the Army, can be subdivided into three periods. The first, the Inter-War period, 1919-1945, saw U.S. Army tank design, heavily influenced by the battles of World War I and the doctrine of her allies. During this period the Army struggled with a definition of the mission and roles of the tank. Technical design was heavily influenced by the requirement to serve as an auxiliary weapon for the infantryman. Later in the period a secondary school of thought developed believing the tank was to be the evolution of the horse in cavalry units. Both these concepts influenced design. Tanks designed during this period, with some modifications, were to be the ones with which America and her allies would fight World War II.

The second period, Post-World War II (1945-1963), was characterized by the successive change of a basic design that was heavily influenced by World War II experience. During this period the combination of developmental subsystems with proven components was to be the norm. Post-World War II design can be traced through progressive evolution of the Patton series of tanks that emerged at the end of the war.

The third period, the current age of U.S tank development, began in 1963 and continues to the present. It began with an abortive attempt to jointly design a tank with the Federal Republic of Germany. Eventually, the Army would field a totally new vehicle incorporating technologically advanced components, the M1 Abrams. The road to the M1 was not smooth. Development was influenced by international political considerations, Army budgets and an uncertainty in the armor community over the role of a new tank.

The Army stands on the doorstep to a new era in tank design. An era where the further evolutions of conventional designs may not meet the requirements of the armored force of the future. To better understand the influences on future designers one must consider how we got where we are today with the M1A1.

THE INTER-WAR PERIOD

The idea of armored fighting vehicles is rooted in antiquity,[1] however it wasn't until the development of automobiles that "battle cars" became practical. This practicality coupled with the need to break the stalemate of the trenches in World War I lead to the development of the first tanks by the British. These "land ships" were the means to return to the mobile warfare that was envisioned at the beginning of the war. This need to return to a war of movement was mandated by the mass casualties in the attritional war that trench fighting had evolved to.

Tanks first appeared on the battlefield during the Battle of the Somme, when, on 15 September 1916, the British surprised the Germans with their employment. Although the results of this first tank employment were less than expected, the tank was on the battlefield to stay. Both the French and Germans were to follow the British lead and develop tanks of their own.

Development and employment of these first tanks were in support of the infantry. Infantry units needed a way to defeat the lethal effects of massed machine gun fires when

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[1]Kenneth Macksey and John H. Batchelor, Tank: A History of the Armoured Fighting Vehicle, (1971): 5-11

advancing across the no-man's land between friendly and enemy trenches. Once the enemy's front line was reached, forces had to break through his barbed wire and trench barriers. Design reflected this need. The resulting tanks were therefore heavily armored, mobile, and capable of providing a machine gun nest that could advance at the pace of the foot soldier. These tanks could provide supporting fires, break through barbed wire barriers and span enemy trenches.

Doctrinal development by the Allies also emphasized the role of the tank as an auxiliary infantry weapon. Just as the rifle aided the infantryman in accomplishing his mission, so did the tank.

The American Expeditionary Force (AEF) was thrust into this environment. American forces, as junior partners in the Allied coalition, were faced with a fait accompli in the doctrinal prosecution of the war. Even though American doctrine stressed maneuver warfare, the AEF soon settled into the doctrinal and tactical norms of the British and French armies. The U.S. Army emerged from World War I "heavily under the influence of French tactical ... doctrine" and the "immediate postwar doctrine of the U.S. Army paralleled that of the French Army."[2]

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[2]CPT Jonathan M. House, Toward Combined Arms Warfare: A Survey of 20th-Century Tactics, Doctrine, and Organization, Combat Studies Institute, Research Survey No. 2 (1984): 69-70.

Not only was the Army influenced doctrinally, but also materially. The tanks used by the AEF were either British or French and these designs reflected their doctrinal thinking. Armor protection was viewed as the principal characteristic of tank design. The prevalent idea that the tank was an auxiliary weapon to the infantryman reinforced this design trend. U. S. Major General Stephen O. Fuqua was to remark:

> "The tank is a weapon and as such it is an auxiliary to the infantryman as is every other weapon that exists."[3]

These two ideas obscured for many years the full use of the tanks power and mobility.[4]

When World War I ended on 11 November 1918 the U.S. Army had on order twenty-three thousand tanks of different models.[5] Most of these were to be ready for a later unneeded 1919 offensive. In 1919 when tank production stopped, the Army had over 1,000 tanks of various designs, of which 952 were Six Ton Tanks.

The Six Ton tank was a U.S. change to the design of the French Renault two crewman tank, the first turreted tank. Additionally, there were one hundred British Mark VIII tanks. The Mark VIII was distinctive for both its

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[3]Orr Kelly, King of the Killing Zone (1989): 68

[4]Richard M. Ogorkiewicz, Armoured Forces: A History of Armoured Forces and Their Vehicles (1970): 8-9

[5]Ogorkiewicz: 189

rhomboidal design and crew of eleven. Completing the U.S. inventory were fifteen Ford Three Ton tanks. The Fords, of U.S. design and crewed by two men, did not have a turret.[6] These were to be the only tanks in the Army, except for a few experimental models, between 1919 and 1936.[7]

The Army's experience in World War I led to formulation of a concept for future war that called for "large infantry armies attacking on parallel routes, supported by massive artillery, tanks, and air power, directed by electrical communications, and transported and supplied by motorized vehicles." This concept for future war was in part responsible for the National Defense Act of 1920 which disestablished the Tank Corps, and directed that Infantry would have proponency for tanks. It further prohibited establishing a tank corps.[8]

In 1922 final definition of the role of the tank was decided to be that of "Facilitating the uninterrupted advance of the rifleman in the attack." While the role of the tank was being resolved, the Caliber Board, a post World War I body formed to determine the future materiel needs of the Army, recommended developing a new single tank design to

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[6]Orgorkiewicz: 189

[7]Kelly: 60-68

[8]US Army, CSI Report No. 1, The Evolution of the Tank in the US Army, 1919-1940 (1982): 3

replace both the Six Ton and Mark VIII tanks.[9] Since these tanks were limited by maximum speeds of only 6 miles per hour, vulnerability to heavy weapons and inability to communicate with supporting artillery, they were barely able to provide infantry support.[10] The Board's envisioned design was dominated by the World War I requirement to cross wide trenches. Therefore the requirements drafted by Brigader General Samuel D. Rockenback, the commander of the Tank Corps in the AEF, called for: a weight not greater than eighteen tons, a speed of up to 12 MPH, a range of 60 miles, armament of two machineguns and protection from 50 caliber armor piercing ammunition at close range. These requirements resulted in the Medium A, also called the M1921. The M1921 weighed twenty one tons, had a maximum speed of 10.1 MPH and had twin turrets, a feature of several future U.S. designs. Armament consisted of a 57mm cannon and a machine gun in one turret with the other turret mounting only a machinegun.[11] There was one produced in 1921 and one each in 1922 and 1925.

Tank design and production moved slowly during the next several years. There were several reasons for the Army's sluggish pace. The first was due to a lack of coor-

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[9]Ogorkiewicz: 190

[10]CSI Report No. 1: 4

[11]R.P. Hunnicutt, Sherman: A History of the American Medium Tank (1978): 10

dination within the Army. Requirements existed for a five ton light tank and fifteen ton heavy tank. These limits were imposed by the Army's truck and bridging equipment capabilities respectively. The Ordnance Department couldn't act until the requirements were approved by the Chief of Infantry. Establishment of the Tank Board, collocated with the Infantry Tank School at Camp Meade, Maryland, in 1924 helped to expedite the approval process.

Another delaying factor was to be the size of the Ordnance Department's tank budget which averaged just $60,000 annually from 1925 to 1931. The final reason for delay was the onset of the Great Depression in 1929 which caused many in the Army to question the economic value of mechanization in a time of austere budgets.[12]

This time of limited Army action in tank development saw an American civilian, J. Walter Christie, step to the forefront in armored vehicle design. Christie, a protege of race car drivers Chevrolet and Olfield, had become interested in tank design. He presented his first tank design to the War Department in 1919, in the midst of World War I demobilization.[13] Christie continued his design experiments until, when in 1928, he unveiled his most remarkable design, the convertible. This tank could travel on its tracks at 42 MPH, or on its wheels, with tracks removed, at

[12]US Army, CSI Report No. 1 (1982): 4-5

[13]Kelly: 69-70

speeds approaching 70 MPH. A 338 horsepower Liberty engine gave it's 7.7 ton weight capabilities that were remarkable for its time. In addition, the vehicle incorporated another Christie invention that provided for independent suspension of each of the road wheels. Christie not only marketed this tank to the U.S., which eventually purchased seven, but also to Poland, Britain and Russia. In fact this design was to become the basis for the World War II, mass produced Russian T-34.[14]

Of the seven Christie's purchased by the Army, three went to the Infantry as the Medium Tank (T3), and four to the Cavalry as the Combat Car (T1). It is interesting to note that these cavalry tanks were designated combat cars to skirt the Congressional prohibition on tanks in any branch but infantry.

The Cavalry by this time had begun to recognize that the continued use of the horse on modern battlefields was limited. A small group of cavalryman began to view the tank as a possible replacement for the horse in mounted units. The tank's striking power and operational mobility offered many advantages and lent itself to the cavalry role of exploitation and pursuit. With Cavalry interest came a design trend towards two types of tanks: one heavy to support the infantry, and the other lighter, less heavily armed and armored to take advantage of its inherent mobility

[14]Ogorkiewicz: 190-191

in the reconnaissance and exploitation missions normally associated with the cavalry. These two divergent trends in design persisted for more than a decade.[15]

In 1933 the Ordnance Department developed the T4 Combat Car, a modification of Christie's designs. The T4 was a promising design that mounted a 12.7mm (50 caliber) machinegun on an eleven ton chassis, was superior in cross country terrain and offered great development potential. Infantry acquired sixteen of these by 1936, but production ceased due, primarily, to budget constraints. Interestingly, the T4 was abandoned while the Russians were mass producing Christie type vehicles.

Development continued meanwhile on light tanks. The T2, a successor to the T1 five-ton tank that was overshadowed by Christie's design, appeared in 1934 at about the same time as the twin turreted T5 Combat Car. These two designs, the T2 and T5, led directly to the M1 combat car and M1A1 light tank in 1936-37. Eighteen M1A1's were produced by 1940. The M2 light tank followed shortly thereafter with consolidation of the combat car and light tank requirements into one vehicle. A total of 72 M2's were to be delivered to the Army by 1940.[16] The M1's were armed with a 37mm main gun while the M2's mounted only a 50 caliber ma-

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[15]Ogorkiewicz: 20, 190-191

[16]Hunnicutt, Sherman: 36

chinegun. This disparity resulted from the differing requirements of the Cavalry and Infantry users.[17]

The M2 was the last American tank design produced during the inter-war period. This period was characterized by American concepts that were isolated from the influence of developmental tank design in other countries. In the U.S., budget constraints forced the Ordnance Department to focus on the development of engines, transmissions and other basic components at the expense of total system development. This fact proved invaluable in World War II.[18]

The American concept for the tank had evolved from a World War I requirement for a heavy vehicle that would serve as an auxiliary to the infantryman to a dual concept of infantry support and employment as mechanized cavalry. The cavalry requirement tended to lighter, more mobile, and less heavily armed and armored designs. This dual concept was formalized in 1939. At a meeting between the Chiefs of Infantry and Cavalry it was agreed that Infantry would be responsible for armored vehicles over 10 tons and Cavalry for those under.[19] Until 1940 medium tanks would remain subordinate to the Infantry branch and consequently design reflected the narrow role of infantry support only. Howev-

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[17]Ogorkiewicz: 192-193

[18]Ogorkiewicz: 201

[19]MG Robert Grow, "The Ten Lean Years," Armor, the Magazine of Mobile Warfare (July-August 1987): 34-42

er, Cavalry, searching for a new steed, had begun to envision the true potential of the tank on the battlefield.

Events were moving rapidly in Europe. Germany's rearmament, its occupation of neighboring territories and eventually her invasion of Poland would ignite World War II. The experiences and requirements of America's soon to be allies were to influence the design of the Army's next tank, the M3 Grant/Lee.

On 1 May 1940 the Army had 464 tanks, the total of U.S. production since 1935. The majority of these were light tanks in the 9-11 ton range mounting only a 50 caliber machine gun.[20]

Several events occurred in 1940 that significantly influenced U.S. tank design and production. In May the world was shocked and stunned by the rapid, German armored blitzkrieg of France. With the use of armored and motorized infantry units working in combined arms, the Germans had brought about the complete collapse of France in just six weeks.

At the same time the U.S. Third Army was conducting maneuvers in Louisiana. Here the Army formed its first provisional armored division from the 7th Cavalry Brigade (Mechanized) reinforced with the 6th Infantry Regiment (Motorized) and a Provisional Tank Brigade. The tank brigade was formed from seven of the Infantry's eight tank

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[20]Ogorkiewicz: 195

battalions. The provisional division performed effectively despite the fact it assembled and formed in only 48 hours.

Army Chief of Staff, George C. Marshall, recognized that neither Infantry nor Cavalry were supportive of mechanization. Even after the events in France and the Provisional Tank Division's performance in Louisiana, neither branch was an advocate of creating armored forces. To solve the problem, and to focus tank design and doctrine, Marshall created a separate Armored Force on 10 July 1940.[21] The single voice for tank development and employment was the Armored Force, commanded by Adna R. Chaffee. Chaffee was a cavalryman who recognized the potentials of the tank. Tank doctrine and design requirements were no longer the purview of the Infantry and Cavalry branches.

With American involvement in the European war looming ever more certain, a general rearmament was begun. Within a month of the Armored Force's creation, the Army let a contract to Chrysler Corporation for the purchase of 1000 M2A1's. The M2A1 modification of the M2 included minor engine and armor changes and the addition of a 37mm gun. However, almost immediately the M2A1 was recognized as obsolete and ineffective against the 75mm gunned Panzer I the Germans had used so devastatingly in France. The M2A1 was

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[21]Christopher R. Gabel, "Evolution of US Armor Mobility," Military Review, 64 (March 1984): 58

therefore canceled after production of only 94 and used only in stateside training units throughout the war.[22]

With the cancellation of M2A1 production, redesign work began that retained the 37mm in the original turret and added a 75mm turreted gun to the right front sponson of the vehicle. Even though a single turret design for the 75mm gun was preferred, it was believed development and production would take too long. The double turreted M3 provided a more powerful tank quickly. Yet there were weaknesses with the M3. The vehicle had a high silhouette and most glaring, the traverse of the sponson mounted 75mm gun turret was severely limited. Even with it's weaknesses the British became interested in the M3 to replace equipment lost at Dunkirk. This expedited development. The M3 prototype was ready in January 1941 and production started in July. With minor modifications to include the addition of a commander's cupola the British would eventually purchase several thousand M3's throughout the course of the war. The M3 Grant (British version) and Lee (U.S. version) became the mainstays of the allied armored forces in the early years of the war and it's several models would provide yeoman service throughout.[23]

To solve the deficiencies with the M3 the Armored Force, on 31 August 1940, submitted a design for a new

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[22]Hunnicutt, Sherman: 46

[23]Hunnicutt, Sherman: 46-47

medium tank. Design goals were to provide a suitable turret for the 75mm gun, a lower height than the M3 and antiaircraft protection. The design, dubbed the T6, was based on the automotively reliable M2A1. With up to 75mm of armor, protection was more than double that of the M2A1. When type classified the T6 was designated the M4 Sherman. The first prototype appeared in September 1941 and mass production began in July 1942. The M4 underwent several modifications resulting in many different models throughout the war, however, its basic armor and armament would not change.

The M4 could probably be called the most successful armored vehicle produced during World War II. In 1943 there were 30,000 produced. Total production of the M4 (of all models) reached 49,234 by the end of the war.[24] The M4's automotively sound design resulted from the Ordnance Department's focus on basic vehicle components in the inter-war period. This reliability lent itself to developing several variants to perform special missions on the battlefield. Among these were the flamethrower (used in the Pacific war), bulldozer, bridge, rocket launcher and amphibious variants. Mine clearing versions that mounted chains or plows and the hedgehog adaption that proved vital in the hedgerow fighting that followed the Normandy invasion, were also developed.[25]

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[24] Hunnicutt, Sherman: 512

[25] Kelly: 83-84

In addition to serving U.S. forces, the M4 was supplied, through Lend Lease, to many of America's allies, to include the British, French and even the Russians. Proliferation was so great that German soldiers were to refer to the Sherman as the T-34 of the west. Considering that the T-34 was the only vehicle produced in comparable numbers, the analogy was fitting.[26]

Despite it's near universal acceptance, there were two major problems with the Sherman, it was undergunned and underarmored against the German Panzers. The M4's standard 75mm gun was ineffective against the frontal aspects of the more heavily armored German Panzers, and its 75mm of armor provided little protection against evolving weapons. The tank mounted German 88mm anti-aircraft gun used in an anti-tank mode proved particularly devastating to the M4. This made a vivid impression on the junior armor officers of the war and later impacted future U.S. designs. The continued fielding of the M4 with these defects was in part due to a desire to keep production numbers high to counter estimated Nazi tank production. These estimates proved, after the war, to be false.[27]

Attempts were made to correct the gun and armor deficiencies. Some allied armies, such as the British with

[26]Hunnicutt, <u>Sherman</u>: 512

[27]Kelly: 84

the 17 pound cannon, upgraded the armament.[28] The U.S. attempted to increase protection against High Explosive Anti-Tank (HEAT) ammunition by trying such things as add-on plastic armor or mounting spikes on the vehicle to detonate HEAT warheads at a safe stand-off distance.[29] However, none of these fixes were applied to the U.S. fleet.

In the fall of 1943 the Armored Force asked to equip 1000 M4s with a more effective 90mm gun for the upcoming invasion of Europe. The Ordnance Department rejected this proposal because such a gun would overload the vehicle. Headquarters, Army Ground Forces further rejected the proposal because the 90mm would lead to a tank killer role for the tank. Tank killing was a role considered to be properly the domain of tank destroyers and field artillery. Tanks, in the doctrine of that time, were utilized in the exploitation and pursuit roles and not in the heavy fight.[30] The argument over the role of the tank raged until events on the battlefield proved conclusively that tanks had to be able to fight tanks and the best tank destroyer was a better tank.[31]

In May 1942, while M4 production was gearing up, design work began on a new medium tank, the T20. The T20

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[28]Kelly: 84

[29]Hunnicutt, Sherman: 220

[30]Hunnicutt, Sherman: 122

[31]Hunnicutt, Sherman: 213

was based on the Sherman, but had significant differences. These included the engine mounted in the rear which allowed a longer and lower silhouette, and a 76mm gun mounted as its main armament. Although it was predicted that production could start in January 1944, in time to have some available for the D-Day invasion, developmental work slowed on the T20. It was feared that a diversion of resources to T20 production would require a drop in the quantities of M4s that would be available to counter German tank production. Additionally, the retrenchment in armor doctrine to the exploitation and pursuit roles, for which the M4 was perfectly suitable, made immediate T20 production unnecessary in the view of Army leaders. Yet a few M4 hulls with T20, 76mm gunned, turrets did appear in Europe before the end of the war.[32]

Work continued on the T20 and it reappeared in the spring of 1945 as the "heavy tank", M26 Pershing. The designation heavy tank stemmed from it's weight of 41 tons. The M26 design, influenced by the need to defeat the German Tiger, mounted a 90mm main gun. Additionally, the Pershing exhibited improved mechanical design over the T20. Most notable of the improvements was a return to a mechanical rather than electrical transmission used in the T20.[33]

[32]Ogorkiewicz: 198

[33]Ogorkiewicz: 199

Several heavy tank designs emerged during the war that were not produced. The M6, 56 ton, tank was ready for production in December 1941. It's 76mm main gun made it the most lethal tank in the world at the time. However, due to the armor doctrine of exploitation and pursuit, the lighter, more mobile, and less heavily armed medium tanks were more suitable for these roles. Heavy tanks returned to favor toward the end of the war with the realization the tank was the best anti-tank weapon. Several turreted designs which appeared in addition to the M26 Pershing were the T29, a 60 ton, 105mm gunned tank; the T30, armed with a 155mm cannon; and the T30E1/T34 sporting a 120mm main gun. These designs reflected the need to defeat and survive battles with the German Tiger IVs that were appearing on the battlefield late in the war. A unique vehicle, the T28, a turretless 85 ton giant that mounted a 105mm gun was designed. The T28 was to serve as an assault gun for the anticipated assault on the Seigfried Line of fortifications that protected Germany's frontier.[34] The war ended before production of these heavy tanks could begin, thus negating their requirement.

American tank designers had learned well the lessons of combat. These lessons would lead to tanks that gave the American armor crewman a vehicle that could hold it's own on the battlefield.

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[34]Ogorkiewicz: 200

Lessons learned during the war proved valuable in the future of tank design. Chief among these were: 1) tanks were the best weapon to defeat tanks, 2) and as such, tanks required heavier armor and armament than the U.S. tanks had entered the war with,[35] and 3) tanks should be designed against the most capable, or greatest projected capability, of the most likely enemy's tanks.

World War II closed with the American M4 Sherman the most prolific armored vehicle of the war. Seeing service in the armies of a number of countries, the Sherman was the mainstay of the U.S. Armored Force, and remained on active duty until the late 1950's. Even though the M4 was preeminent, a new tank, with greater capabilities, whose design was a result of combat experience was beginning to appear. The M26 Pershing was the vehicle on which the Army's operational tanks were based into the mid 1980's.

POST WORLD WAR II

Planning for the post-war Army began with the victory in Europe barely won and fighting still continuing with Japan. The Army Ground Forces review board met in June 1945 to determine the equipment needs of the Army after victory was secured. Among the requirements identified was the need for development of a family of three tanks: A light tank in the 25 ton range, a medium tank weighing 45 tons, and a 75

[35]Ogorkiewicz: 201

ton heavy tank. In addition, experimental work on a 150 ton super heavy tank was called for. The Board further recommended investigation of such technological innovations as autoloaders and multi-fuel gas turbine engines.

In January 1946 the Stillwell Board, headed by General Joseph Stillwell, recommended the Army discontinue developing towed anti-tank weapons and to further disband the Tank Destroyer force. The rationale for this recommendation was recognition of the tank as the best anti-tank weapon and development should concentrate there. The Stillwell Board further recommended that developmental emphasis should be on basic systems components, a return to the developmental strategies of the inter-war period.[36]

Several factors were to lead to a declining role for the tank in the Army. Chief among these were force reductions caused by budget cutbacks.

Following the end of World War II, America remained true to her heritage and began a massive and rapid demobilization. Consequently in the budgets of the post-war years the Army faced major reductions. The perception of many was that the Army had no role in the nuclear warfare strategy that dominated political and military thinking. The Air Force, with it's capability to conduct strategic nuclear

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[36]Hunnicutt, Patton: 9-10

warfare, and the Navy instead were to gain the lion's shares of defense appropriations.[37]

Armor strength went from a high of 16 tank divisions in the war to one understrength division by 1948. More than 2000 M26 Pershings were placed in storage, while the M4E3 Sherman, a 76mm armed modification of earlier versions, was the most numerous tank in the force.[38]

A second, contributing factor to the decline of the role of the tank in the Army was the effectiveness of man-portable HEAT weapons. The success of the American bazooka and German panzerfaust against tanks in World War II had convinced many the tank was not suitable for concentrated, independent employment. The belief that tanks could easily be defeated by man-portable weapons manifested itself in a resurgence of the dual concept of infantry support and cavalry exploitation which was tank doctrine before the war.[39] Tanks were again assigned to Infantry regiments and divisions (a company and battalion respectively), however these were not filled to authorization in many cases.

While development of the family of three weights of tanks recommended by the Army Ground Forces Review Board was continuing, development of an interim medium tank was under-

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[37] R. P. Hunnicutt, Patton: A History of the American Main Battle Tank (1978): 9

[38] Ogorkiewicz: 200-201

[39] Ogorkiewicz: 29

way. A new engine and transmission for the M26 Pershing were coupled with an improved 90mm gun turret. In July 1948 these tanks were designated the M46 Patton, in honor of the Army's most famous tank warrior of World War II, General George S. Patton. Eight hundred M46s were authorized in the 1949 budget with an additional 1215 M26s planned for conversion in 1950.[40]

This plan, however, did not survive the North Korean attack on South Korea. On 25 June 1950, the North Korean Peoples Army, led by the World War II vintage, Russian made T-34 tanks of its armored brigade, invaded the Republic of South Korea.[41] The plans to upgrade the American tank fleet were soon thrown into disarray. The M26s scheduled for conversion were, instead, rushed to Korea to make up for the shortages in materiel and combat losses. In addition, M4A3s and M26s with which American forces were equipped were no match for the T-34.[42]

The situation in Korea predicted a change in design focus by the Army in November 1950 to reflect gun caliber and not weight. The new designations called for a light tank (the T41) to be armed with a 76mm gun, the T42 medium tank armed with a 90mm gun and the T43 heavy tank mounting a

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[40]Hunnicutt, Patton: 14

[41]Roy K. Flint, et al., The Arab-Israeli Wars, the Chinese Civil War and the Korean War The West Point Military History Series (1987): 69

[42]Hunnicutt, Patton: 17

120mm gun. This means of designating designs reflected a change to emphasize the lethality of the system.[43]

To further correct the deficiencies identified on the Korean battlefield, the T42 experimental turret was wedded to the M46 automotive system. This hybrid was designated the M47 medium tank. The T42 turret used a rangefinder, for improved accuracy and mounted a 90mm gun. This was combined with the M46 hull's low weight and excellent power, which had proven advantageous in Korea's rough terrain. 8,576 were built by the time production lines closed in November 1953.[44]

Although the M47 was declared obsolete by the Army in 1957, it was to stay in the service of such countries as Iran, Spain, Israel and Pakistan until the mid-1970's. Thus, what had started as an emergency stopgap solution would serve for more than two decades. Its sound design and ease of modification to meet evolving battlefield threats were key to its longevity.[45]

The war in Korea again proved the need for a viable armored force in the Army and may have been a reason for the establishment of the Armor branch by Congress in 1950. The tank again proved itself invaluable in the anti-tank role on the battlefield as it was much more effective than the World

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[43]Hunnicutt, Patton: 35

[44]Hunnicutt, Patton: 27-52

[45]Hunnicutt, Patton: 78

War II vintage manportable anti-tank weapons that were employed by U.S. forces.

The need to design tanks against the correct threat was also clear. The U.S. tanks, as had been the case of the M2A1 in 1940, were obsolete before they ever made an appearance on the battlefield. Although the U.S. had received two T-34 tanks from the Russians in a Lend-Lease swap at the end of World War II, little technical analysis was performed on these vehicles. Instead a small post war technical intelligence community concentrated its analytic effort on captured German equipment. Yet, very little of the products of these efforts were incorporated into U.S. design work.[46]

Although post-World War national strategy had identified the Soviet Union as the main threat to the U.S. and its allies, there was no concurrent translation of that strategy into Army materiel development. Army captured materiel analysis and tank design efforts focused on the war just concluded and not on the capabilities of the most probable future threat, the Red Army. Over one-third of the Russian Army was composed of armored formations by 1950.[47] Korea brought the U.S. into battle against Soviet equipment and the design deficiencies of U.S. tanks were readily apparent on the battlefield. After Korea, Soviet equipment

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[46]William L. Howard, "Technical Intelligence and Tank Design," Armor, the Magazine of Mobile Warfare (January-February 1985): 24-29

[47]Ogorkiewicz: 29

would become the main effort against which technological intelligence would focus.[48]

During the Korean War design work continued on the T42 whose turret was used in the M47. Requirements for the T42 had initially been established in September 1948 and were highlighted by the requirement for a 50 caliber coaxial machinegun, a 90mm main gun and a crew of four. This effort resulted in 1953 as the M48 and was distinctive for its boat shaped bow and one piece cast rounded turret.[49] In 1957 when the M46/47 series of tanks were declare obsolete, the M48 became the main battle tank of the Army. The M48 went through several modifications to upgrade its capabilities through the years and it remained in service with the Army for nearly two decades.

Concurrent with T42 development, the design of a heavy tank, the T43, was in progress. The T43 was an outgrowth of the M46/47, using the same 810 horsepower V-12 engine. The main differences were a 120mm main gun and heavier armor which increased it's weight to 53.5 tons. The T43 was type classified the M103 Heavy Tank in 1956 and was to see only limited service in the Army into the mid 1960's.[50] It's weight, resulting in decreased mobility, and

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[48]Howard: 27

[49]Hunnicutt, Patton: 92

[50]R.P. Hunnicutt, Firepower: A History of American Heavy Tank (1988): 124

increased fuel consumption and maintenance, worked against its acceptability. However, the M103s 120mm gun was preferred over the M48's 90mm by the few Army tank crews that served on it. The M103 saw an extended life with service in the the Marine Corps. The Marine Corps eventually designated the M103 as its main battle tank, and it saw service in the Corps into the early 1970's. Only the threat of the Russian T43 Stalin, which mounted a 122mm cannon, and the T-10 heavy tanks kept it in service that long.[51]

During the mid 1950's national strategists were trying to come to grips with the implications of nuclear weapons on warfare. In the strategy of massive retaliation that gained primacy in the Eisenhower administration, ground forces were seen as little more than a trip wire to a large scale strategic nuclear response. In an effort to counter this, the Army postulated that ground operations on a nuclear battlefield favored armored forces.[52] The inherent radiological protection and mobility of armored vehicles facilitated their employment in such an environment. The May 1955 Task Force (TF) Razor test seemed to prove the point. At a Nevada nuclear test site, TF Razor, composed of manned armored vehicles, was positioned within 3000 yards of a nuclear detonation. TF Razor was not only able to survive the explosion's multiple effects, but could move into and

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[51]Ogorkiewicz: 202-203

[52]Ogorkiewicz: 30-33

exploit the area.[53] Coupled with the recent effectiveness of armor in Korea, the proven capability to survive and fight on a nuclear battlefield gave tanks a new life in the Army.

In 1958, Army Chief Of Staff, General Maxwell D. Taylor, appointed a blue ribbon commission to look at requirements for U.S. tanks for the period 1965 and later. The Armament for Future Tanks or Similar Combat Vehicles (ARCOVE) panel determined that long range, command line of sight (CLOS) chemical energy warhead missiles would be the best armament to defeat future threats. To achieve the necessary research and development funds in an era of tight budgets, the committee further recommended the Army cut back on developing kinetic energy ammunition and the guns to fire it. General Taylor approved the report's recommendations and added one further stipulation. Gone were the light, medium and heavy designations for tanks. The future Army tank fleet would be composed of two types of tanks. The first would be an Armored Reconnaissance/Airborne Assault Vehicle (AR/AAV) and the second a Main Battle Tank (MBT).[54] No longer would the Army design tanks based on size of gun or weight. There would be one tank, the MBT, for armored and mechanized units of the heavy forces. The AR/AAV would meet the specialized requirements of reconnaissance and

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[53]Ogorkiewicz: 205

[54]Hunnicutt, Patton: 149

airborne units. The ARCOVE report sent the Army on a design tangent from which it would not return until Abrams development began in the 1970's.

Influenced by the ARCOVE report, the Bureau of the Budget prohibited M48 funding after the end of fiscal year (FY) 1959. In an attempt to overcome this prohibition, the Army developed a low risk, interim solution until development of the new MBT. The reliable M48 chassis was outfitted with a ballistically improved turret, a British 105mm cannon, and a new V-12 air cooled diesel engine was installed. On 16 March 1959 this hybrid was type classified as the M60 MBT.[55] Designed as an interim vehicle, the M60, in modified form, is still on active duty with the Army today.

In the 23 year period that has followed M60 type classification, several modifications have been made to the vehicle resulting in successively improved versions. The A1 model replaced the M48 type cast elliptical turret with a new, improved elongated turret. Further modifications of the A1 have added a gun stabilization system, replaced the power train components with reliability improved parts, and added a passive sighting system. The A3 model further replaced the coax machinegun with a more reliable Belgian model, replaced the coincidence rangefinder with a laser rangefinder, replaced the gunner's primary optic sights with a thermal imaging system and added an exhaust smoke screen-

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[55]Ogorkiewicz: 202; Hunnicutt, Patton: 157

ing system. While some improvement has been made in ammunition capabilities, the 105mm gun and armor remained unchanged from original versions.[56]

Although not mentioned above, its worthwhile to review the short lived A2 model. The A2 was less a change than a major redesign of the M60. The A2 carried out the ARCOVE recommendations by removing the 105mm gun and replacing it with a 152mm gun/missile launcher. The gun could fire either a 152mm chemical energy round or the Shillelagh guided missile. To accommodate these changes a redesigned turret incorporating an infrared missile guidance system was developed. The old reliable chassis was unchanged. The gun/missile system however proved unreliable and required extensive maintenance support. Of about 540 M60A2s produced between 1973 and 1975, all were quickly warehoused by the Army.

While the Army was fielding the M60, and its modifications for the MBT role, development of the second type of tank stipulated in the ARCOVE report was underway. In the mid 1960s the 16 ton M551 Sheridan AR/AAV began fielding. The M551 was destined for Cavalry units to serve in a reconnaissance role and the 82nd Airborne division as its deployable, air droppable armor. While the chassis and propulsion system proved highly reliable, the same 152mm gun-/missile system as on the M60A2 was a nightmare. Many of

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[56]Hunnicutt, Patton: 169

the same technical problems that the M60A2 experienced were exacerbated by the Sheridan's lighter weight which magnified the affects of 152mm gun on the sensitive missile guidance system.

The Army began withdrawing the Sheridan from active service in Cavalry units in 1979, placing most in depot storage. However, a few M551s were retained and modified to replicate Soviet armored vehicles and are now used at the Army's National Training Center to portray enemy units. The Sheridan also remains on active duty with one battalion assigned to the 82nd Airborne Division. Even though the M551 is considered obsolete, budget constraints have prohibited fielding a replacement. It's deficiencies however, were highlighted to Army and Congressional leadership during the December 1989 U.S. invasion of Panama, and studies are underway to find a more capable replacement.[57]

A NEW TANK

Disaffection in the Army for yet another interim tank of piecemeal design (i.e. the M60), began to manifest itself in the early sixties. The Soviets were introducing a new tank, the T-62, that called into question the capabilities of the "tired, old, second rate M-60".[58] Onto the

[57]"Nunn, Montgomery praise intervention," Army Times (January 15, 1990): 12

[58]Kelly: 21

stage came Robert S. McNamara, President Kennedy's Secretary of Defense. McNamara, a paragon of American business management philosophy, arrived from his executive position with Ford Motor Corporation to bring current business management practices to the Pentagon. McNamara, concerned that only 5% of NATO's weapons were jointly produced, saw a joint weapons system development program between the U.S. and another NATO country as a way to reduce weapons procurement and operations cost. Additionally, a joint effort could increase NATO member integration, and bring about an increase in NATO countries commitment to the common defense. The system he chose to achieve this effort was the tank. The Army, which wanted a new tank, and McNamara, who wanted a better procurement process, became partners. The U.S. reached an agreement in 1963 with West Germany to produce a tank. The tank, to be operational in about seven years, was designated the MBT-70.[59] The goal of this joint effort was to "use advanced technology to produce a true supertank."[60]

Almost from the beginning of the program American and German designers were at odds. The Germans wanted a relatively small agile tank, with a gun capable at short distances and the best nuclear protection available. These requirements reflected the German need to fight primarily in Central Europe. The Americans, wanted a tank that could

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[59]Kelly: 25-26

[60]Kelly: 22

fight anywhere in the world. This required a heavily armored vehicle, missile capability (ARCOVE requirements) at long distances and little need for nuclear protection. Added to this were cultural and procurement process differences between the two countries.

Costs, however, were to doom the program. In 1968, development costs had risen to 303 million dollars, almost quadrupling the original estimates of 80 million. Spiraling development costs, coupled with the fact that estimates on the production vehicle cost were approaching one million dollars each, the program was canceled, by mutual agreement with the Germans, in 1970.[61]

The MBT-70's design incorporated several technologically advanced features. An improved 152mm gun/missile system, a radiation capsule for the crew, an autoloader and a hydropneumatic suspension that allowed the vehicle to raise and squat were used. The experience gained and lessons learned were to lead to the Army's next design effort, the XM-803 program.[62]

Almost immediately upon cancellation of the MBT-70, the Army began the XM-803 project. It capitalized on the successes of the MBT-70, however the program suffered from a lack of vision by the Army's tank crewman. Tankers began to question the use of a gun/missile system, the autoloader and

[61]Kelly: 37

[62]Kelly: 40

three man crew. BG Bernard R. Lucsak, U.S. Army Tank Program Manager (PM Tank) was to remark, "The Armor community cannot seem to agree on what it wants in the way of a new MBT. There is ... internal dissension within the armor community concerning the role of the tank--if any."[63] With such internal doubt in the Army about the direction of the program, Congress cancelled the XM-803 program in December 1971. Congress included in the cancellation act twenty million dollars for studies on future tanks. Studies that were to lead to the Army's current MBT, the M1 Abrams.

The M1 program began on 20 January 1972, only one month after cancellation of the XM-803 when the Tank Task Force was chartered. The intent of this new program, as agreed to by Congress and the Pentagon, was not to develop the best possible tank as had been the case with the MBT-70. Rather, the goal was to develop the best tank possible for a limited amount of money. To justify its production this new tank had to be significantly better than the M60s and M48s then in service. The limited amount of money was considered to be a production cost of $500,000 per tank.[64]

The Tank Task Force was chartered for a five month effort. Its task was to define the required capabilities desired in a tank within the limits set out above. To accomplish its task the TF was divided into three teams. A

[63]Kelly: 38

[64]Kelly: 94-95

Mission Need (MN) team looked at Soviet tanks and what was required to beat them in the period of the next 20 years. A Components Team, looked at off the shelf components, items already developed, for inclusion in the tank. The final grouping of the TF was a Systems Integration (SI) Team that conducted computer analysis and cost studies of the various identified design requirements. The 33 members of the TF represented a solid cross section of Armor officers, many of which held advanced degrees.[65]

The center of the new tank program was established at Fort Knox, Kentucky, the Army's Armor Center and School. Commanding Fort Knox at that time was MG W. R. Desobry. Desobry was a tanker with combat experience in World War II and Korea and a strong feeling for what capabilities were required in a new tank. Foremost among these were the need not to be outgunned. His personal experience as a tank commander against the more heavily armed German and Russian tanks convinced him the gun was the key and should be able to kill the enemy's most capable tank.[66] Weight was also a key consideration for Desobry, for weight would determine the vehicle's tactical mobility and agility.

Reinforcing Desobry's concern with weight was a letter from five general officers with World War II armor experience. This group advocated a weight in the 45 ton

[65]Kelly: 93

[66]Kelly: 89

range.[67] With this additional support, the Army's point man for tank development and commander of the Tank Task Force, exerted great influence in defining the requirements for the new tank.

From the TF's work and the results of a questionnaire distributed to all armor soldiers throughout the Army to find out what they deemed essential in a tank, a prioritized list of required capabilities was developed. These nineteen requirements, in order, were: 1) Crew survivability, 2) Surveillance and target acquisition performance, 3) First and subsequent round hit probability, 4) Time to acquire and hit, 5) Cross country mobility, 6) Complementary armament integration, 7) Equipment survivability, 8) Environmental impact, 9) Silhouette, 10) Acceleration and deceleration, 11) Ammunition stowage, 12) Human factors, 13) Producability, 14) Range, 15) Speed, 16) Diagnostic aids, 17) Growth potential, 18) Support equipment and 19) Transportability.[68] These 19 characteristics would guide the work of contractors developing prototypes which were to compete for final selection by the Army. The Army's selection of three major components for the new tank would have significant impact on the final product.

At the time of the TF's work, a few key individuals became aware of a highly classified British armor devel-

[67]Kelly: 96

[68]Kelly: 109

opment. This armor, known as Chobham, offered a significant increase in protection. There was however, a weight penalty associated with it's use. To bring the tank to the desired level of protection, a two foot thickness of Chobham was required. This would increase vehicle weight to 58 tons. Not wanting to further sacrifice mobility, Desobry wanted the upper limit on weight set at 52 tons. CSA designate, Creighton Abrams, decided in September 1972, that the extra protection offered by Chobham was worth the weight gain and its use was mandated. This would prove to be significant as the new armor would dominate design, weight, cost and manufacture of the tank.[69]

The type of main gun and engine were also decided early in the program and politics figured significantly in both decisions. Most players in the design process were confident in the capabilities of the British designed 105mm gun and ammunition already in use on the M60. However, a political trade-off for the German purchase of an AWACS aircraft forced the Army to adopt the German 120mm gun. This gun, which could not be incorporated into design before production was to begin, would make its appearance in the M1A1.[70] This decision, with the guns application to 2,220

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[69]Kelly: 122-128

[70]Kelly: 179-191

tanks, added five billion dollars to the cost of the M1 program.[71]

To achieve the horsepower to weight ratio of 25 (hp) to 1 (ton), the Task Force thought necessary, a significant improvement over the 13-1 ratio of the diesel engine powering M60's was required. Two such diesel engines were under development, one in the U.S. and the other in Germany. Upon comparison, the German engine was clearly the better and offered greater potential. To avoid buying foreign manufactured engines and to eliminate the risk associated with the American diesel, it was decided to incorporate a turbine engine. While the turbine enjoyed success in aircraft, it was not proven in ground vehicle use.[72] This political decision to buy American resulted in serious delays in initial tank production due to design flaws in the engine. Additionally, the turbine's increased fuel consumption and maintenance requirements would significantly increase the Operations & Sustainment (O & S) costs of the vehicle.

The recommendations of the Tank Task Force, decisions on armor, gun and engine, and many other decisions throughout the design and development process led to the M1 Abrams main battle tank. Since production of the M1 began on 28 February 1980, several modifications have been added. In addition to armor changes, the replacement of the 105mm

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[71]Kelly: 214

[72]Kelly: 143-145

gun with the German 120mm and the installation of an NBC overpressure system resulted in the M1A1. Further modifications to include the installation of a Commander's Independent Thermal Viewer (CITV), suspension system upgrade and the addition of a Driver's thermal viewer, are known as the M1A2. With all of these modifications the M1A2 will approach 70 tons in weight and two million dollars in cost per vehicle. A significant departure from the limits originally envisioned for the Abrams.

The Army has continued modernization of the M1 beyond the A2 program. This effort has been known as the M1A3 program, and the Block III tank program is now a part of the Armored Systems Modernization (ASM) program. The ASM program and the tank portion of it will not be discussed due to changes on-going in this effort. Review of the tank design resulting from this effort cannot be conducted until the Congress and DOD agree on the final direction of the program.

CONCLUSIONS

In the historical review conducted in this chapter three recurring trends in the U.S. tank program have emerged. Tank design against the incorrect threat, austere post-war military budgets and a resulting design focus emphasizing component improvement rather than holistic vehicle design are characteristics of past U.S. efforts.

Incorrect threat identification resulted in the Army taking the field in both World War II and Korea with tanks that were outgunned and underarmored. After World War I, U.S. post-war doctrinal and tank development efforts focused on correcting the deficiencies identified in that war. This backward looking focus resulted in U.S. ignorance of the tank development going on in Europe. The shocking German armored blitzkrieg of France in May 1940 finally awakened the Army to tank development on the international scene. However this reawakening was too late to develop and field tanks that were equal to the German panzers. Instead, the U.S. would take the field with outdated designs developed during the Inter-war period. Post World War II design efforts suffered from the same problem, development was focused on the wrong threat. The efforts of the U.S. tank design community focused on building a tank as good as the Germans had in World War II. The failure of tank design to consider the U.S. strategic focus on the Soviet threat resulted in U.S. forces being bested on the battlefields of Korea by the old, but very capable Soviet T-34.

Since the end of the Korean War, the U.S. has correctly identified the Soviet Union as the most lethal threat to the national interests. With the current thawing in East - West relations, and Soviet moves away from a military economy there is a public trend to discount the lethality of her armed forces. Besides the U.S., the Soviet Union remains the only military superpower in the world today. While the possibility for conflict with the Soviet Union is growing more remote, Russia remains the most lethal threat to U.S. national interest and objectives.

As the probability for conflict with the Soviet Union is lessening, the possibility for regional conflict is growing. Instability in such regions as Eastern Europe, the Middle East, Central and South America and South East Asia is on the rise. When this instability is fed with the increasing proliferation of modern weapons, the potential for regional conflict increases. As many of these areas are vital to U.S. interests, the possibility for American military involvement in contingency operations increases.

The challenge for future tank design is to address this two faceted threat. Future tanks must provide capability against the lethal but low probability threat of the Soviet Union and the high probability of involvement in regional conflicts against enemy forces that are equipped with sophisticated modern Soviet designed weaponry.

Past post-war demobilizations resulted in significant reductions for peacetime military budgets. The current international environment has created what can be characterized as a post-cold war mentality. Historical American distrust of large standing armies has been exacerbated by the wide spread perception that threats to the nation no longer exist. The resultant public demand for military demobilization and redirection of military spending to more pressing national concerns is reminiscent of previous post-war stand downs of the armed forces. The design approach of focusing on tank system components, rather than total new system development, in austere budget periods, is a characteristic of the U.S. tank program. This approach has been forced by a lack of money. It would appear this trend will continue for the foreseeable future in Army tank development efforts.

SUMMARY

This chapter documented an examination of the historical dimension of U.S. tank design and development from its beginnings following World War I to the present. This examination identified three distinct periods in tank design in the U.S. The first period began immediately following World War I and was characterized by an influence of allied doctrine on American military thought. This influence, particularly French, emphasized maneuver war in which the infantryman was the key component. All other weapons, to include the new battlefield weapon, the tank, were to aid the infantryman in his mission. Early tank design reflected this requirement.

America became isolated from European thought on the uses and mission of tanks, so there was little change to the initial doctrine for tanks until the late 1930's. It was during this time some forward looking cavalrymen began to recognize the capabilities that tanks offered. Cavalry requirements began to influence design. It was not until early 1940, with the German blitzkrieg of France and the success of a provisional tank division in U.S. maneuvers that the Army's leaders recognized the advantages that tanks offered for the battlefield. Even though a separate Armored Force came into being in 1940, tanks remained limited by doctrine to the exploitation, pursuit and infantry support roles that had evolved in the 1930's. This, coupled with the design work already in progress, resulted in tanks that were modified in design to meet emergency wartime requirements. It would not be until the end of World War II that tanks were considered to be the best anti-tank weapons. This realization would breed a new tank design that was capable of exploiting its inherent advantages.

The M26 Pershing would dominate post World War II tank design, the second period of U.S. tank development. The M26 incorporated into its design, lessons learned on the battlefields of World War II. This 1945 product would be the vehicle on which the Army's main battle tanks into the mid 1980's would be based. A combination of budget constraints and national emergencies mitigated against new production tanks and lead to successive modifications of the M26. These changes would result in the M46, M47, M48 and M60 tanks. Later versions of the M60 remain in service today.

The latest era in U.S. tank development efforts began in 1963 with the joint U.S.-German attempt to co-produce a new tank, the MBT-70. The MBT-70 program would eventually fail, but would lead to the U.S. XM-803 program and the M1 Abrams effort. In 1981 the Army began fielding the Abrams, 36 years after its last truly new tank design.

The 70 years of American tank development have been characterized by budget constraints, changing doctrine, and a belated focus on the threat and design efforts that have focused on components of a tank system and not the entire system. This last element is a result of budget inadequacies that resulted in successive upgrades to a basic design.

These historical trends are worthy of consideration by those in the Army that are responsible for developing future Army tanks. As the Army goes forward with materiel development plans for the future, a future that is clouded by a changing threat, changing doctrine and severe budget constraints, the lessons of the past could serve as guides around the pitfalls that lie in the road ahead.

CHAPTER 4

STRATEGIC AND DOCTRINAL CONSIDERATIONS

INTRODUCTION

Chapter 3 reviewed the historical dimension of the U.S. tank program. This chapter examines three areas that must be considered in any future tank development. Surveyed are U.S. national strategy and the military strategy that supports it and the Army's AirLand Battle doctrine. The national military strategy and Army doctrine tell us what will be required of a future tank. An understanding of strategic and doctrinal requirements is necessary to determine the viability of a turretless tank. Before proceeding with examination of these factors, a look at how the Army determines materiel requirements is warranted.

ARMY REQUIREMENTS PROCESS

The process which the Army uses to determine its requirements is the Concepts Based Requirements System (CBRS). CBRS, as described in TRADOC/AMC Pam 70-2, Materiel Acquisition Handbook, is a systematic and flexible approach to determining the Army's future needs and resolving current battlefield deficiencies.

Developing an umbrella concept initiates the CBRS process. An umbrella concept is the formal expression of what the Army must do on the future battlefield. It is the overarching, all encompassing, description of the way it will fight. This concept is derived from the requirements imposed on the Army by the national military strategy. When a concept is approved by the Army's leadership it gains the status of doctrine.

A thorough examination of the doctrine (the present approved concept) or the umbrella concept for the future is coupled with an in-depth review of current and future missions, current and projected world-wide threat, historical experiences and technological forecasts. This review identifies the needs, or requirements, for the Army. Additionally, proponents such as Armor, Infantry, Field Artillery, etc., conduct Mission Area Analyses (MAA) to identify deficiencies in the capabilities of the programmed force. The programmed force is the force structure and materiel that are planned in the next five year budget period.

Once CBRS needs and MAA deficiencies are identified, solutions are sought. This solution determination is an orderly process that examines the domains of doctrine, training, leader development, organizations and materiel (D-T-L-O-M). Conducting this search in D-T-L-O-M order ensures costs are minimized. It is easier and less expensive to change doctrine than to change training, organizations or materiel. If the solution for a problem lies within the doctrinal realm, the search stops there. However, as is most often the case, no solution or only a partial solution is found and the search continues to the next domain(s) until there is resolution.

Developing new materiel is the last resort. It is the most expensive, and has impacts, with associated costs, on the other four domains. If, for example, the solution for a need is determined to be a more effective field artillery cannon, three options are available. The first is procurement of an off-the-shelf weapon. This is no more than the purchase of existing commercial, other service, or foreign developed equipment. These are called non-developmental items (NDI). If NDI equipment will not meet the requirements, modification of existing equipment is the second option. This modification takes advantage of existing training and logistics support systems and is known as Product Improvement/Pre-Planned product improvement (PI/-P3I). The last and most expensive option is a new development program.

In a new development program, costs accrue from developing and fielding the new weapon system, and also from its impacts on the other domains of CBRS. In the case of a new developmental artillery piece, changes may be required in artillery organizations, development programs for artillery leaders, artillery training programs and possibly even artillery doctrine. These changes will manifest themselves in many ways to include monetary costs and personnel turbulence. Due to its cost and impact on the force, development of new materiel potentially has great impact on the Army.

The Army's requirements and materiel acquisition processes are a logical, systematic approach focused on the implementation of its doctrine. The Army's doctrine is how it will conduct operations directed at implementing the national military strategy. Therefore, an examination of strategy should begin to identify the requirements for future tank design.

U.S. NATIONAL SECURITY STRATEGY

From the previous discussion it is evident the design of a future tank must support the Army's doctrine. That doctrine is derived from the U.S. National Military Strategy (NMS). NMS is derived from the U.S. national security strategy.

U.S. National Security Strategy is laid out in President Reagan's January 1988 report to Congress, "National Security Strategy of the United States." The stated objective is to "protect and advance the values of American society." The national security strategy incorporates the elements of national power: political, economic and military, into a comprehensive plan to achieve this objective. The values the security strategy seeks to protect are identified in such foundation documents of the U.S. government as the Declaration of Independence, the Constitution and the Bill of Rights. Values such as human dignity, personal freedom, individual rights, peace and prosperity and the pursuit of happiness have been the guiding principles of American government since its inception.

These values are given more concrete expression as national interests. The five key national interests expressed in President Reagan's report are: 1) The survival of the U.S. as a free and independent nation with its fundamental values intact and its institutions and people secure; 2) A healthy and growing U.S. economy to provide opportunity for individual prosperity and a resource base for our national endeavors; 3) A stable and secure world, free of major threats to U.S. interests; 4) The growth of human freedom, democratic institutions, and free market economies throughout the world linked by fair and open international trading systems; and 5) Healthy and vigorous alliance relationships. Objectives in support of these interests are: 1) Maintain the security of our nation and our allies; 2) Respond to the challenges of the global economy; 3) Defend and advance the cause of democracy, freedom and human rights throughout the world; 4) Peaceful resolution of regional conflicts that threaten U.S. interests; and 5) To build effective and friendly relationships with all nations with whom there is a basis of shared concern.[1]

The principal threat to U.S. interests and objectives identified in the report is the Soviet Union. The events that have occurred recently in the Soviet Union and Eastern Europe have convinced many people in our government and public that the Soviet threat no longer exists. While this may be true in the realms of political and economic power, the Soviet Union maintains a very capable military force. While these people see the downsizing of the Red Army as an indicator of Soviet retrenchment, others consider it an elimination of the fat which will result in a "leaner, meaner" Soviet Army. Ongoing internal strife in the Baltic states and other republics may serve to show the true nature and extent of Soviet demilitarization.

Identified as additional threats to U.S. interests and objectives are the possibilities for mid intensity regional conflict. Such areas as the Korean peninsula, the Middle East and Indochina are potential hot spots. These, coupled with the threat of low intensity conflicts in developing third world nations, international terrorism and narcotics trafficking, present a multispectral challenge to American military forces.[2]

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[1] U.S. Government, National Security Strategy of the United States (January 1988): 3-4

[2] U.S. Government, National Security Strategy: 6

NATIONAL MILITARY STRATEGY

The translation of the military element of national power is effected through the National Military Strategy (NMS). U.S. Military Strategy is based on deterrence, and has been the cornerstone of defense policy since World War II. The goal of deterrence is to persuade any potential enemy that the result of any aggressive act or endangerment of U.S. interests will cost him more than the gain he would realize. The strategic doctrine of Flexible Response implements deterrence policy.[3]

Flexible Response is the keystone of the National Military Strategy and is complemented by the policies of Collective Security and Reducing and Controlling Arms. Each of these three pillars of the NMS have implications for tank design requirements. A review of the three pillars and their components is conducted in the following paragraphs.

Flexible Response is composed of three mutually supportive components: Direct Defense, the Threat of Escalation and the Threat of Retaliation. Direct Defense has the intent of meeting aggression at the point of conflict, wherever in the world it may occur. Introducing U.S. forces to defeat an attack on a U.S. ally or to protect U.S. interests in a region are examples of Direct Defense.

[3] U.S. Government, National Security Strategy: 13

The Threat of Escalation implies that the U.S. will escalate hostilities to whatever level is required to gain an end state that is favorable to the U.S., its interests and its allies. A further implication is that hostilities would not be confined in a manner that an adversary could afford. The costs would far outweigh the advantages the potential adversary could accept. U.S. and NATO policy reserving the right of first use of nuclear weapons to stem a conventional attack in Western Europe is an example of the Threat of Escalation.

Finally, the Threat of Retaliation raises the prospect of a direct attack on the adversary's homeland in response to aggression. U.S. capability and resolve to retaliate in like manner for a Soviet Nuclear attack on the U.S. utilizes the Threat of Retaliation.[4]

To achieve the capabilities necessary to implement Flexible Response doctrine, five critical Defense programs have been identified. Modernization of Strategic Nuclear Forces, development of a Strategic Defense capability, modernization of Non-Strategic Nuclear Forces, enhancing Deterrence and Defense Against Non-Nuclear Aggression, and enhancing military capabilities to conduct Low Intensity Conflict (LIC) operations are key to implementing Flexible

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[4]U.S. Government, National Security Strategy: 14

Response.[5] Of these five programs, enhancing Defense against Non-Nuclear Aggression and enhancing LIC capabilities hold the most impact for future tank development.

Deterrence and Defense against Non-nuclear Aggression is comprised of four elements that ensure a capability against non-nuclear aggression. First, maintaining an effective robust conventional non-nuclear force and the defensive capabilities it provides is imperative. An effective conventional force not only convinces an adversary of the costs of his potential aggression, but also lowers the threshold for the employment of nuclear weapons.

Second, a qualitatively and quantitatively balanced conventional force is essential. A simple one for one match up with a potential enemy in major items of equipment is not the answer. U.S. interests are increasingly global with many different requirements in varied regions of the world. The capability to project and sustain conventional forces into any region of the world is necessary. Within the context of declining resources, reducing the number of combat forces in order to gain a capability to move them may be required. However, the qualitative edge, the lethality of those forces must be maintained. The U.S. cannot afford to send conventional forces into combat, as was done in Korea, with obsolete equipment.

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[5]U.S. Government, Report to the Congress: Frank C. Carlucci, Secretary of Defense, Fiscal Year 1990 (January 1989): 35-44

Third, flexible, forward deployed conventional forces that are able to be projected into any part of the world are necessary. Flexibility implies the capability to move on short notice. Inherent in flexibility is the ability to package the proper type and mix of forces to defeat the threat in a given area of the world. Forward deployed forces, such as U.S. forces in Germany, provide a U.S. presence. This presence is proof of American commitment to an ally or an alliance. Forward basing provides the infrastructure onto which deploying follow-on forces can fall in and promotes the efficient use of alliance resources. A subset of forward basing is the pre-positioning of equipment in potential world trouble areas. Pre-positioned equipment is maintained in a combat ready status awaiting the arrival of the soldiers required to operate it. Critical to flexibility and to meeting threats in contingency areas is the requirement for power projection. The availability of air and sealift means and the ability of conventional forces to be deployed aboard such means is essential.

Fourth, a rapid mobilization capability is required. Of consideration here is not only an effective Reserve component structure, but also an industrial mobilization capability. Key to industrial mobilization is the maintenance of a warm production base and the early procurement of long lead items.

An enhanced chemical defense capability, integrated with the four areas discussed above, will enhance U.S. deterrence and defense against non-nuclear aggression.[6]

As for the enhancement of LIC capabilities, the need to conduct peacetime contingency operations is critical. Short of conventional military operations, limited duration military strikes, demonstrations and shows of force may be required to protect U.S. interests. It is imperative that U.S. forces employed in these operations be structured to meet the on the ground threat in a contingency area. Possible threats run the gamut from ill-equipped guerilla forces to heavy, mechanized forces. Key to structuring contingency forces for a particular operation are the availability and deployability of the equipment necessary to defeat the threat. Tanks are part of that necessary equipment.[7]

Flexible Response has guaranteed U.S. security for almost 30 years and conventional land forces have been an integral component of that strategy. To remain a contributor to the national defense, Army Chief of Staff, General Carl E. Vuono identifies three capabilities the Army of the 1990s must have. Vuono's white paper, "A Strategic Force for the 1990s and Beyond," recognizes Lethality, Versatility and Deployability as required attributes for the Army in the 90s and beyond.

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[6]U.S. Government, Carlucci Report: 41-42

[7]U.S. Government, Carlucci Report: 43-45

Lethality is "the assured capability to defeat an opponent, winning as quickly as possible while preserving.... the lives of our soldiers."[8] Modernization is crucial to maintaining a lethal army. Planned, prioritized modernization in the spheres of doctrine, training, leader development, organizations and materiel. Modernization must capitalize on American strengths in technology and soldier quality.

Versatility is required to meet increasingly capable sophisticated and divergent threats to U.S. national interests. Versatility is achieved by maintaining the right proportions of Active and Reserve components, the correct number and mix of heavy, light, and special operations forces and adequate sustainment stocks.

The global nature of U.S. interests and the U.S. coalition based strategy require the rapid deployment of U.S. forces to counter threats to these interests and alliances. The significant element in achieving deployability is strategic lift. The availability of sea and air resources to move Army forces to a potential trouble spot is essential. Equally important is the capability of Army materiel to be moved in available lift assets. The Army's future development of materiel must consider the restraints imposed by strategic lift assets. As more of the Army becomes a

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[8]U.S. Army, A Strategic Force for the 1990s and Beyond (January 1990): 10

continental United States based force, the importance of deployability increases.

The Army must ensure its lethality, versatility and deployability if it is to continue to play a role in the national security strategy. Consideration of these attributes is required in all planning for the future. If not, the Army may find itself standing on the brink of obsolescence, tied to the strategies of the past.

Complementing the long pole of Flexible Response in the tent of NMS is the strategy of Collective Security. Collective Security is apparent in America's network of alliances with countries that have common values. Alliances serve the U.S. in two ways. First, an alliance allows us to join with our allies in defense of common interests as far forward from the U.S. as possible. Secondly, the combined capabilities of the U.S. and its allies provides a much greater deterrent than could any one country alone, and the costs of defense are shared.[9]

Since the end of World War II the policy of Collective Security has ensured the security of America and her allies. The U.S.'s alliance relationships run the spectrum from the multinational NATO alliance to bilateral agreements exemplified by the U.S. - Philippine pact. Alliance participation has presented a unified deterrent to Soviet adven-

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[9]U.S. Government, Carlucci Report: 49

turism and allowed projection of U.S. power into all corners of the world.

Although coalition strategy has proven successful in deterring Soviet aggression and ensuring peace, the public outcry for national budget reductions has called into question the need for such a strategy in the future. However, the need to protect far flung U.S. interest will mitigate a retreat into the isolationist policies of the past. Instead, modifications in the alliances resulting in a change in the role the U.S. plays in each is certain to emerge.

Contributing to the U.S.'s changing role, is the emergence of an increased sense of national pride in allied countries. This factor most often demands a decreased U.S. presence and increased reliance on internal resources.

It is inconceivable that the U.S., or its allies, will abandon a proven policy that has been instrumental in maintaining world peace for more than four decades. Whatever the result of the domestic and international debate over alliance participation, Collective Security remains crucial to U.S. national security.

The third leg of the NMS is Reducing and Controlling Arms. Initiatives such as the Intermediate-Range Nuclear Forces (INF) Treaty, the Strategic Arms Reductions Talks (START), chemical arms negotiations and the Conventional Stability Talks (CST) are foundations of Arms Control. Each of these efforts impacts conventional forces to some degree. Agreements limiting nuclear weapons will require the maintenance of a credible conventional force deterrent. The CST negotiations directly impact the quantity and type of conventional forces that will be allowed in Europe. The repercussions of arms control agreements on the lethality, versatility and deployability of the Army must be a prime consideration.[10]

The requirements of national security and the military strategy to protect the U.S. determines the roles and requirements for the military services within that strategy. These requirements are translated into the "how to fight" procedures by the doctrine of the service. The service's doctrine then, drives its materiel requirements.

AIRLAND BATTLE DOCTRINE

The Army's warfighting doctrine is AirLand Battle (ALB). ALB was developed out of the strategic requirement to defeat the massed armored echelons of the Soviet Army on the plains of Central Europe. U.S. Army Field Manual (FM) 100-5, Operations describes AirLand Battle as "...the Army's approach to generating and applying combat power at the operational and tactical levels" of war. Albeit, AirLand Battle doctrine was generated from the need to achieve victory in a high intensity conflict in Europe, it is globally applicable to the entire spectrum of war. AirLand

[10] U.S. Government, Carlucci Report: 73-78

Battle is the foundation for world wide Army operations in Mid and Low Intensity conflict as well. The following discussion of AirLand Battle is extracted from FM 100-5.

Important to the understanding of AirLand Battle is a knowledge of the dynamics of combat power. Combat power is the ability to fight. Combat power is measured by the effects created from combining maneuver, firepower, protection and leadership. The objective on the battlefield is to apply, at the decisive place and time, combat power superior to what the enemy can apply. This superior combat power is built by the commander's skillful application of maneuver, firepower, protection, and leadership in a sound, flexible, forcefully executed plan.

Maneuver is the movement of forces in relation to the enemy to secure or retain positional advantage. It is the way to concentrate forces at the critical place and time. Maneuver will rarely be possible without firepower and protection. To be effective, maneuver demands a host of considerations, among these, air and ground mobility, and reliable logistical support.

Firepower provides the destructive force necessary to defeat the enemy's ability and will to fight. Firepower aids maneuver by suppressing enemy fires and disrupting his formations. Additionally, firepower exploits maneuver by destroying enemy forces and their will to fight. Firepower, however, can be used in lieu of maneuver. The massing of fires, depending on the tactical situation, may be an alternative to massing forces.

Protection is the conservation of the fighting abilities of the force. Protection of the force is necessary to enable the force's use at the decisive time and place. Two interrelated considerations comprise protection. First are the actions taken to counter the effects of the enemy's weapons. Active and passive measures are included. An example of passive protection is a tank's armor. Tank fire to suppress enemy weapons is an example of active protection actions. The second component of protection is soldier health and morale. Fielding a highly survivable tank certainly improves a soldier's morale. Caring for his physical and spiritual needs ensures his health.

The fourth, and most essential, component of the dynamics of combat power is leadership. Leadership provides purpose, direction and motivation in combat. Only the skillful leader can provide the most effective mix of maneuver, protection and firepower at the decisive place. Leadership skill is developed through dedicated study of the art and science of war.

AirLand Battle is characterized by delivering rapid, unpredictable, violent blows to the enemy centers of gravity. The intent of these blows is to secure and retain the initiative and the imposition of our will on the enemy. Attacking enemy centers of gravity will destroy the coherence of enemy operations throughout the battlefield. Critical to AirLand Battle operations is the identification of the enemy's center of gravity.

A center of gravity is the vital component of an organization that, when disrupted or destroyed, will unbalance or destroy the remainder of the organization. Centers of gravity can be tangible and easily identifiable. A unit's command and control node, or it's artillery force could be such a center. An abstract component of the unit may also be a center of gravity. The morale of an enemy's soldiers or the mental and physical conditions of his commanders, may be his unhinging weakness. There is no approved criteria for determining a center of gravity. Identification of a center of gravity will vary with the unit, its composition, readiness and a host of other factors. Centers of gravity will vary at the different levels of operations: tactical, operational and strategic. Identification of centers of gravity is crucial. The success of AirLand Battle is contingent on the ability to identify and attack enemy centers of gravity.

The bedrock to the success of AirLand Battle to achieve success on the battlefield are the tenets of: Agility, Initiative, Synchronization and Depth. These four standards are the guiding principles for the employment of all Army forces throughout the spectrum of conflict. These tenets guide not only the human facet of the Army, but it's materiel dimension as well. The materiel of war must enhance the commander's ability to exercise agility, initiative, synchronization and depth.

Agility is the ability to act faster than the enemy. It is the ability to operate inside his decision and execution cycles. Agility applies to both the physical and mental plane of operations. Physically, units and leaders must act quickly and move fast and efficiently to beat the enemy to the decisive place. Mental agility is the ability to "think on your feet", to react rapidly and without hesitation to changing situations. The capabilities of Army materiel must reinforce the agility of both units and leaders on the battlefield.

Initiative on the battlefield means being able to set or change the terms of battle to favor you. It is manifested in retaining your freedom of action while imposing your will on the enemy. Vital to maintaining operational initiative is the exercise of individual initiative by leaders at all levels. The ability to act independently within the commanders concept is crucial. Materiel that is lethal, mobile and survivable ensures maintenance of initiative.

Synchronization is the structuring of battlefield activities in time, purpose and space. The objective of synchronization is the application of maximum combat power at the decisive place and time. Synchronization is the maximum utilization of all resources, applied when and where they will be most decisive.

Depth is the conduct of operations in space, time and resources. Depth can be physical, as in the depth of a battlefield position; or it can be mental, as is the case when a commander looks beyond present operations to anticipate future enemy actions. Physical depth is that part of the battlefield where attrition of the enemy begins. Operations in this area set the conditions for success in the close battle. Mental depth enhances the agility and initiative of individuals and units.

AirLand Battle partitions the battlefield into three areas in which operations will be conducted. Army units and materiel will be required to fight in the close, deep and rear areas. Failure in any of these areas offers potentially serious consequences for the battlefield commander.

The area of close operations is best described as the main battle area. It is the area where battles will be lost or won; the head-knocking area. The depth of this area is a function of the level of operations. At the battalion, the close battle area is limited to the ranges of the unit's direct fire weapons systems, not more than five kilometers. At division and corps the close area is deeper. Its bounds are set by the capabilities of the assets at the commanders disposal to influence the battle. Ranges of indirect and aviation fires establish the division and corps close battle area and include the close, deep and rear area of subordinate units.

The Deep area is where operations are conducted against uncommitted enemy forces. The purpose of deep operations is to disrupt the enemy's freedom of action and the tempo of his operations. Most importantly, deep operations structure the close battle by ensuring favorable terms are maintained in the close area. Actions include operations to delay, disrupt or destroy the enemy before his arrival in the close area.

The Rear area is where operations occur to the rear of forces in contact. Operations in the rear area seek to ensure friendly freedom of action through sustainment and command and control activities.

Leaders at all levels must understand the interrelationships of these three areas of operations and their combined impact on the results of battle.

The adherence to the tenets of Agility, Initiative, Synchronization and Depth, in close, deep and rear operations will ensure success on the battlefield. Understanding these concepts is required for the warfighter, but also their comprehension by combat and materiel developers is important. These personnel, combat and materiel developers, determine the requirements for, and design of, Army equipment. This equipment must reinforce the battlefield implementation of AirLand Battle and aid the application of combat power at all locations on the battlefield.

AirLand Battle is an evolving doctrine. Initiatives such as the AirLand Battle-Future (ALB-F) and ALB-F Nonlinear concepts seek the evolution of ALB principles into the next century. The development of these concepts is in progress and an attempt to address them here would be futile. Refinement of these concepts is occurring within the context of constantly changing budget, threat and international realities. Such flux precludes their consideration in this thesis. Examination of the final approved ALB-F and/or ALB-F Nonlinear concepts, and their impacts on tank design, is therefore left for future researchers.

CONCLUSIONS

In the review of U.S. military strategy and Army doctrine conducted in this chapter, three factors have emerged as design considerations in future U.S. tank development. The Army must have equipment that is deployable, lethal to the threat and supports the implementation of it's doctrine on the battlefield.

The U.S.'s global interests and increasingly U.S. based Army demand deployable equipment. A capability for rapid sea and air transportation to any potential trouble spot in the world is required. Once there, the ability to defeat the enemy's weapons is critical.

The threat to global U.S. interests and objectives is two fold. First, the Soviet Union remains the most lethal threat to the U.S. The recent significant changes inside the Soviet Union and the breaking away of its East Bloc satellites have convinced many people the threat to Western Europe and the U.S. no longer exists. Yet, the Soviet Union maintains a formidible, first world military machine.

It can be assumed that these capabilities will be maintained or even increased for the foreseeable future. The Soviet armed forces are experiencing an unprecedented reduction in personnel, equipment and budgets. The influx of western technology which is a result of improved East - West relations, and an internal military change in focus from quantity to quality, create the potential for the Soviet military to gain parity or even superiority over the West in weapons design.

The Soviet government's statements of peaceful intentions in no way mitigate the capabilities of its armed forces. In the post-cold war euphoria that has gripped the world, this fact must not be overlooked.

As a result of the enormous change that has occurred in the world, the probability of direct conflict with the Red Army has diminished. However, the conditions for regional conflict around the world are on the rise.

U.S. involvement in regional conflict is the second element of the threat that challenges this country. Many regions of the world in which the U.S. has interests are faced with growing political, economic and military instability. As the factors that create these instabilities continue to grow and are fed by the availability of modern weapons, the potential for conflict increases. As the potential for conflict increases, the probability of contingency military operations to protect U.S. strategic interests and citizens in these areas grows. Operations such as those conducted in Panama and Grenada would appear to offer the greatest potential for employing U.S. military forces for the foreseeable future. To meet this challenge, Army materiel must be rapidly deployable and lethal to whatever threat exists in the conflict area.

Future tank design must consider these threats. The very lethal Soviet armed forces and the highly probable U.S. military involvment in regional contingency operations are the threats against which tank design must focus.

The Army's equipment, to include tanks, must aid the battlefield commander in implementing AirLand Battle doctrine. The need for maneuverability, firepower and protection guide tank design. Providing these capabilities in a tank assists the commander in synchronizing his battle and provides physical agility to the force.

Strategic and doctrinal requirements provide the basis for design of the materiel of war. Design of future tanks must seek to satisfy these requirements, if not, then strategic and doctrinal objectives are unattainable.

SUMMARY

The goal of this chapter has been to acquaint the reader with the determinants of Army requirements. After conducting a brief review of the Army's materiel acquisition process, a brief examination of the National Military Strategy and Army doctrine was conducted.

Integration of the strategy for the military element of national power, with the strategies for the political and economic elements, forms a comprehensive national security strategy. To ensure unanimity National Military Strategy is developed by the National Command Authority. The U.S. National Military Strategy is typified by the policy of deterrence. Deterrence is achieved through the strategic doctrines of Flexible Response, Collective Security and Arms Control. These three pillars of deterrence guide the armed services in the developing their warfighting doctrine.

Since 1982, the Army's warfighting doctrine, has been AirLand Battle. The principles of AirLand Battle are the guidepost for the employment of Army forces and steers the development of Army doctrine, training, organizations and materiel.

An understanding of the National Military Strategy and AirLand Battle doctrine is essential to designers of the future Army. It is out of these two areas that the requirements for the Army in the years ahead will be determined.

CHAPTER 5

TECHNICAL DESIGN CONSIDERATIONS

INTRODUCTION

Reader appreciation for technical design considerations in tank development is the goal of the following discussion. These technical considerations impose constraints (must do) as well as restraints (can't do) on tank design. An understanding of these interrelated factors is necessary to determine the viability of a turretless tank. Before proceeding, a definition of what a tank is and identification of its universal requirements are needed.

A tank is defined in Webster's Ninth New Collegiate Dictionary as: "an enclosed heavily armed and armored combat vehicle that moves on two endless metal belts." Contained in this definition are the three primary requirements for a tank: mobility, lethality and survivability. These three requirements generated efforts that resulted in the first tanks in World War I and have carried through in all tank designs since. Mobile, protected firepower is what the tank brings to the battlefield.

THE TRIGON OF DESIGN

Mobility, firepower and protection are the hallmarks of tanks. Richard Simpkin has developed a visual means to aid in an understanding of the interrelationship of these design factors. In his book Tank Warfare, Simpkin proposes that tank design can be viewed as a triangle.[1]

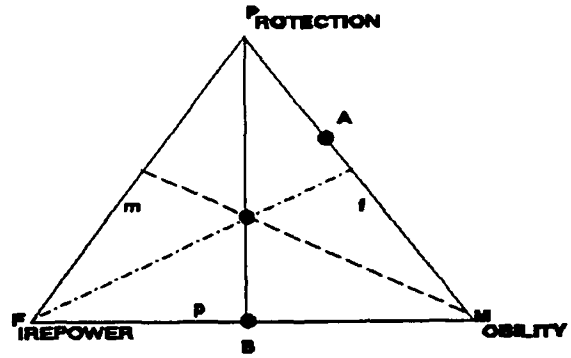

FIGURE 5-1

Each of the corners of this "marketing man's triangle" represents the maximum of either mobility, firepower or protection. The side opposite a given corner is the baseline or 0 capability for that design factor. A line running from the baseline to its corresponding opposite angle represents the possible range for that design factor, none to maxiumum. For example, a line running from the protection baseline (p) to its opposite angle (P) represents the range of protection that can be incorporated into a tank design. No protection at the baseline to maximum protection represented at the corner. The protection capability of a particular design will fall somewhere along this line when plotted. A balanced, versatile design,

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[1]Richard Simpkin, Tank Warfare (1978): 82

when plotted on the three lines representing the range of mobility, protection and firepower, would fall in the center of the triangle, where the lines intersect. When drawn it would appear as shown in Figure 5 - 1.

In this diagram point A, on the f line midway between the M and P corners, represents some kind of mobile shelter with no firepower capabilities. Likewise point B, on the p line, represents an unarmored gun carriage.

Although the center point represents a design that is versatile and balanced, no tank building country has, or desires, such a design. National strategy, doctrine, history, threat and other considerations will serve to emphasize one or two of the three design categories above the other(s). Such emphasis serves to unbalance the design effort.

Simpkin has conducted a subjective evaluation of international tank design philosophies. Within the design trigon he has plotted where the tank design philosophies of the US, UK, USSR and Germany fall. Simpkin's evaluation appears in the diagram at Figure 5 - 2.

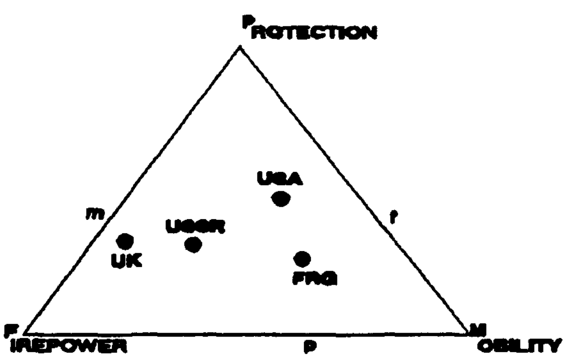

FIGURE 5 - 2

As can be seen from the plots, the US and USSR tend toward the center. However, the US has slightly more emphasis on protection and mobility than firepower while the USSR edges toward increased firepower and mobility over protection. These trends are evident in the tanks produced.

The Chapter 3 review of the M1 program identified the nineteen prioritized characteristics desired in that new tank. Crew survivability was considered the most important requirement in M1 development. Also, the desire by many key personnel in the development effort for a high horsepower to weight ratio for the tank resulted in high mobility. The result was the M1 that had high capabilities in mobility and firepower, and reduced firepower capabilities with the older 105mm gun.

The design trigon provides a general representation of the mix of mobility, protection and firepower that is desired or contained in any tank design. The translation of these general requirements into specific needs is not possible without an understanding of the subordinate technical considerations in each of the mobility, firepower and protection design categories.

MOBILITY

Mobility is the capability to move or be moved. Mobility for fighting vehicles is required in the tactical, operational and strategic levels of operations. Tactical or battlefield mobility is best seen as the ability to move with speed and freedom of maneuver while in contact.[2] A tank darting across an open area or moving between primary and alternate firing positions is an example of tactical mobility. The tactical aspect of mobility is a matter of exposure time.[3] The critical element here is to minimize the time a tank is exposed to enemy observation and fires. The most important design factor influencing this capability is the power to weight ratio of the vehicle, i.e. the amount of horsepower the engine can generate per ton of vehicle weight. The M1's higher, 28/1, ratio provides much better tactical mobility than the 13.1/1 ratio of the M60A3.[4]

Ground pressure and ground clearance contribute to tactical mobility. Ground pressure is the amount of weight per square inch of ground the vehicle has along its ground contact surface. Increased ground pressure reduces the range of ground types on which a tank can operate. The lower the ground pressure, the easier it is for a tank to travel over softer, less trafficable terrain. The 13.1 pounds per square inch (PSI) ground pressure exerted by the M1 is among the highest in the world today.[5] To reduce

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[2]Simpkin: 100

[3]Simpkin: 104

[4]R.P. Hunnicutt, Patton: A History of the American Main Battle Tank (1984): 443

[5]Gerald A. Halbert, "Elements of Tank Design," Armor, The Magazine of Mobile Warfare (November-December 1983): 39

ground pressure, a reduction in vehicle weight or an increase in track surface is required.

Ground clearance is the distance between the ground and the belly of a tank. Clearance impacts the type of terrain and small obstacles that can be maneuvered over. Higher clearance provides more maneuverability. The disadvantage in increasing clearance is that as ground clearance grows so does the vehicle's height. A ground clearance of 450-500mm is probably optimal,[6] offering an acceptable height for a tank.

Operational mobility is the capability for extended and speedy road movement. This capability is either inherent in the vehicle or can be provided with heavy equipment transport trucks or rail assets. Operational mobility is the ability to displace within the context of the operational level of war. The U.S. Third Army's reorientation from west to north, and subsequent attack into the German flank during the Battle of the Bulge, exemplifies operational mobility.

Inherent vehicle operational mobility is primarily affected by transmission ratios, rolling resistance[7] and reliability of suspension and power train components. Rolling resistance is the resistance generated by a vehicle's tracks. If, for example, engine power is doubled,

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[6]Simpkin: 107

[7]Simpkin: 105

speed is increased by only 50% due primarily to track resistance. Transmission ratio is that percentage of engine power that is applied to the tracks. The capability of the vehicle's transmission further limits the increase in speed generated by increasing engine power. Due to a combination of these factors, limits of the transmission and rolling resistance, the German Leopard II's 50% increase in power to weight ratio over that of the Leopard I resulted in just a 4.6% increase in speed.[8]

Design factors that further limit operational mobility are weight, width and amphibious capability. The weight of a vehicle determines the number of bridges it can use in an operational area. Weight is also a consideration in truck transport. The M1A2 with a weight in excess of 69 tons exceeds the capability of current Army heavy equipment transporters (HET). Width restricts both rail and HET movement. Width design of the M1 was limited to 144 inches based on the capability of European rail flat cars and tunnels.[9] The width of the M1 exceeds the width of current Army HETs by 41.5 inches.[10] An overhang of 20.75 inches on each side of the HET is necessary when hauling an M1 tank.

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[8]Simpkin: 105

[9]Orr Kelly, King of the Killing Zone (1989): 140

[10]Gerald Halbert, "Elements of Tank Design," Armor, The Magazine of Mobile Warfare, (November-December 1983): 36

It can be assumed that in an operational area there will be some water obstacles to movement. An amphibious (swimming) capability for a vehicle greatly expands its operational flexibility. The problem with providing this capability is weight. 36-42 tons is considered maximum vehicle weight for an amphibious vehicle.[11] Anything in excess of 42 tons requires special float or bridging equipment. In lieu of a swimming capability, a snorkel arrangement such as the Soviets have developed, or extensive engineer bridging capabilities, like those a part of Western armies, is required. A reduction in vehicle weight would therefore lend itself to an amphibious capability increasing operational mobility while decreasing support requirements.

Strategic mobility can best be called deployability. Deployability is the ability to be deployed on air and sealift assets. Deployability is a requirement unique to the U.S., and possibly the Soviet Union. The U.S.'s far flung interests and system of global alliances could require the introduction of Army forces into any area of the world. It is imperative that such forces arrive in the conflict area with a capability lethal to the threat, whatever it may be. Considering that more than a dozen developing countries have in excess of 1000 MBTs, tanks will be a required part of a contingency force.

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[11]Simpkin: 102

The deployability of an armored vehicle is limited by the physical characteristics of its size. The capabilities of air and sealift assets determine the deployability of a vehicle. The height, weight and width limits of aircraft and ships are crucial to armored vehicle deployability.

The U.S.'s capability to rapidly deploy M1 tanks is limited by the capabilities of its heavy airlift asset. The Air Force C5 Galaxy, for peacetime planning purposes, can only carry one M1. Deployment of a tank battalion of 58 tanks would require a minimum of 58 C5 sorties. These 58 sorties would only deliver the tanks of the battalion to the deployment area. The remainder of the battalion's equipment, vehicles and personnel would require even more airlift assets. This inability to rapidly deploy lethal forces could seriously jeopardize future contingency operations.

Sealift asset restrictions are not as confining as airlift. The critical consideration with sealift however is time. The movement of CONUS based forces to seaports of embarkation, loading and sailing time requires more time than is available in a contingency operation. Also, to be considered in sea deployment, is the availability of improved port facilities or suitable beaches on which to offload equipment. If a port is unavailable then the availability of a beach with the capability to support the ground pressure exerted by a tank is critical.

Deployability is a crucial consideration in U.S. armored vehicle design. The U.S.'s wide range of global commitments requires the Army and it's equipment to be rapidly deployable, on a moments notice, to meet threats to the national security. Design of armored vehicles must reinforce that capability.

SURVIVABILITY

Survivability is the ability to survive on the battlefield. There are two facets to survivability in armored vehicle design, system survivability and crew survivability.[12]

System survivability is achieved through a combination of two factors, direct protection and indirect protection. Direct protection is the ability of an armored vehicle to withstand the effects of a hit by an enemy weapon and continue to perform its role on the battlefield. Indirect protection is achieved by not being hit.

Direct protection is gained from the vehicle's armor. In a tank, the weight of steel needed for the structure also protects against nonspecialized attack, such as 7.62mm bullets and shrapnel from HE rounds. In a conventionally designed tank this represents about 23% of total vehicle weight. Another 5% in weight is added to protect the tank

[12]Simpkin: 110

belly against mines and provide all around protection against 12.7mm bullets and 20-30mm cannons. To achieve protection against the specialized anti-tank attack of HEAT and KE rounds an armor thickness 10-12 times greater than the all around level is required. Due to the limited amount of weight trade-off available, uparmoring against anti-tank attack can only be applied to about 10% of the tank surface.[13] The 10% that is uparmored is usually the frontal 60 degree arc measured either from the rear of the turret or tangential to the turret. This distribution is based on the probability of being hit.[14] The sides, rear and top remain at a lower level of protection and thus are vulnerable to anti-tank attack.

Direct protection can be achieved by increasing the amount of armor which carries a significant weight penalty. An alternative is the use of new types of armor that provide greater protection, pound for pound, than steel. The Chobham armor used on the M1 and reactive armor seen on Soviet tanks are examples of improved armor.

Anti-tank weapons evolution will find a way to defeat these armor advances. Such programs as the U.S. TOW-2B anti-tank missile and near term technological advances in kinetic energy weapons are effective counters to advanced armors. These enhanced anti-tank capabilities are achieved

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[13] Simpkin: 111

[14] Halbert: 37

at a fraction of the cost of uparmoring. To achieve complete protection from current 105mm and 120mm tank guns, French tests have concluded that a tank weighing in the 80-100 ton range is required. To provide protection against top attack weapons to levels equivalent to frontal standards, tank weight could well reach 150-200 tons. Given that the costs of tanks increase in direct proportion to weight, it is not cost effective to continue uparmoring in response to new anti-tank threats.[15] If direct protection is not the answer, then the solution would appear to lie in indirect protection.

Indirect protection concerns the chance of not being hit.[16] Several factors contribute to hit avoidance. Height is a consideration. If height can be decreased the chance for detection is decreased.

Height is a result of the tanks turret height, hull height and ground clearance. Ground clearance was addressed in the previous discussion of mobility. Turret height is dictated by the size of the main gun, main gun depression angle, and the need for the loader to stand to load main gun rounds. Hull height is controlled by the size of the engine and the height of a seated driver, about 1 meter. Reducing

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[15]Craig Koerner and Michael O'Conner, "The Heavily Armored, Gun Armed Main Battle Tank is Not Optimized for Mechanized Warfare," Armor, The Magazine of Mobile Warfare, (May-June 86): 11-12

[16]Simpkin: 110

the requirements imposed by these factors will reduce the total vehicle height. An equally important consideration in reducing height is weight reduction. With a decreased frontal volume to protect, protection levels can be maintained while simultaneously reducing weight.[17]

In addition to height reduction, other elements contribute to indirect protection. Battlefield mobility decreases exposure times. Smoke grenade launchers and vehicle smoke screening systems protect against detection. Self entrenching devices, that allow the tank to dig itself in, and devices that limit infrared, visual and audio signatures assist in indirect protection.

No matter how extensive indirect protection measures may be, they can not offer total protection. There will be instances when a tank will be detected, engaged and hit by the enemy. Direct protection in these instances is not total either. Continuing the cycle of uparmoring to meet evolving anti-tank weapons is not feasible. There is a limit to the weight growth of a tank. Barring the introduction of some revolutionary technological advancement in protection systems, guaranteed system survivability is not possible. If system survivability is not possible, then emphasizing crew survivability is crucial.

Crew survivability is achieved through direct protection, indirect protection and reducing the lethality of a

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[17]Halbert: 36

penetration once it occurs.[18] Threats to crew safety include fires that are generated and fed from onboard components such as ammunition and fuel. Fifty percent of vehicle combat losses can be attributed to fuel and ammunition fires.[19]

Ammunition is particularly vulnerable to fire. The propellant contained in ammunition and in missile rocket motors and the explosives in mines and pyrotechnics all contain their own oxidizer. This oxidizer serves to fuel the fire even though countermeasures are taken to prevent it. Solutions to ammunition vulnerability rest in improving the explosives and propellants and designing safety measures in the tank. The use of liquid propellants, semi-combustable ammunition cases and low power explosives reduce the hazard from ammunition.

Design considerations include the use of vented ammunition magazines that vent the force of exploding ammunition away from the crew and out of the tank. This feature, along with a ballistic door separating the crew compartment from stored ammunition, is incorporated on the M1. The use of water jackets, a technique used in the M4 Sherman by the British, prevent heat build-up in ammo stores.[20] Ballistic blankets protect ammunition from susceptibility to

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[18]Simpkin: 115

[19]Donald R. Kennedy, "The Search for Safer Combat Vehicles: How Close Are We Getting," Armor, The Magazine of Mobile Warfare (September-October 1988): 39

[20]Halbert: 38

penetration by shrapnel. External ammunition stowage not only reduces crew vulnerability but also aids a rapid rearm capability and is conducive to the use of an autoloader. Internal stowage can be improved by placing ammunition below the turret ring in the more heavily armored hull.[21] Incorporation of features such as these, coupled with improved munitions, can substantially aid crew survivability.

Danger from fuel fires is much less than that experienced in World War II and is significantly less than that posed by ammunition. A shift to diesel fuels from highly volatile gasoline, the use of automatic fire extinguishing systems and self-sealing fuel tanks have contributed to crew safety. Safety from fuel fire can be further improved by providing jettisonable fuel tanks. Jettisonable fuel tanks not only separate the crew from the fuel but also provide additional armor capability. Fuel can attenuate the shaped charge jet from a chemical energy anti-tank weapon.[22] Storing fuel in hull tanks increases its protection and provides additional crew protection from radiation hazards.

Besides decreasing ammunition and fuel vulnerability such considerations as design of inflammable crewmember uniforms and location of escape points on the vehicle aid crew survivability. Imagination in tank design that takes

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[21]Kennedy: 39-41

[22]Simpkin: 116

into account the full range of the possible, will greatly increase crew survivability.

With the current and evolving lethality of chemical and kinetic energy weapons, system survivability may be a dangerous myth.[23] Given the vulnerability of the system, indirect protection and crew survivability would seem the design focus of choice. Just as airplanes are limited by weight restrictions, tanks may well be also. Fighter aircraft design has focused on not being hit and survival of the crew even if it has been hit. Tanks are approaching the limits of weight growth, a growth mandated by an emphasis on direct protection. Future tank design will require an emphasis on indirect protection and crew survivability.

LETHALITY

"Lethality, the chance that a hit will kill, is a function of the residual energy of attack after penetration of the armor and of the proportion of the armored volume affected by the attack."[24] A tank's lethality is achieved by it's main gun, the ammunition it fires, the fire control system and secondary armament.

The tank's main armament is its primary means of killing enemy tanks. In the mid 1960s the U.S. trend to missile systems as main armament was evident in the M551

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[23]Simpkin: 119

[24]Simpkin: 87

Sheridan and M60A2. Both of these vehicles employed the Shillelagh missile system as their main armament. The Shillelagh proved unacceptable and was dropped from later versions of the M60. Besides inherent technical problems, the Shillelagh exhibited limitations that are common to all missile systems. Missiles require a longer flight time to reach their target, which results in increased exposure time and reduced rates of fire. Additionally, missile bodies are bigger and heavier than cannon rounds and require more storage space, resulting in reduced on-board quantities, or basic load.[25] For these reasons and improved fire control systems that have allowed cannons to become more accurate at longer ranges, the cannon reemerged as the weapon of choice for tank main armament.

Tank cannons offer the advantages of high rates of fire, fire and forget projectiles, smaller ammunition, a variety of ammunition types and a shoot on the move capability. As armor protection has increased and fire control systems have become more accurate at longer ranges, cannon size has increased to provide the power necessary to maintain lethality. At the end of World War II the 90mm cannon was considered large and was effective. Increasing cannon size has resulted in a cannon within the 120mm range as the norm on most of the world's current MBTs. It can be expected that this trend to larger guns will continue. The

[25]Halbert: 39

next generation of tanks may well possess cannons in the 130-150mm range.[26]

Increasing cannon size requires a larger caliber, heavier, round of ammunition. Larger, heavier rounds offer two primary considerations for future design. First, as round size increases, the number of rounds that can be stored on board the vehicle decreases. Requirements for on-board stowed rounds are derived from Army doctrine, the potential threat, probabilities for a hit and a kill given a hit, in-depth analysis of target presentation rates and rates of fire. Upgunning the M1 to the 120mm gun resulted in a drop in basic load size from 63 rounds to 40. This may not be as bad as it first appears. If the larger caliber round offers a higher potential for probability of kill, then the trade-off in number of available rounds may be worth it.[27] Whatever the number of required basic load rounds, size of the rounds will affect design.

The second factor to be considered in increasing round size is the weight of the round. As caliber increases past 120mm, round weight will also increase. This increasing weight will approach the limits of the capability of the tank loader to manipulate the round inside the turret. To

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[26]Simpkin: 99

[27]John C. Woznik, "Developing a Tank Autoloader," Armor, The Magazine of Mobile Warfare (Sep-Oct 1989): 12

ensure safety in handling and loading efficiency, an autoloader may be required on tanks mounting larger guns.[28]

Maintaining the battlefield lethality of a tank by increasing gun size impacts future design. Allowance for not only the increased physical size and weight of the cannon, but also its ammunition, demands design consideration.

Tank cannon ammunition is basically of two types, chemical energy and kinetic energy. Chemical energy (CE) rounds use their explosive power to burn a hole through a tank's armor. Kinetic energy (KE) rounds use a dense mass of metal, accelerated to high speeds, to punch a hole through armor. Both rely on the residual affects of these penetrations to cause damage to vehicle systems and crewmen.

The current use of compound and reactive armors has lessened the capabilities of current CE ammunition. However in the pendulum of armor vs. attack, improved capability for CE rounds can be expected. Currently though, KE rounds are the primary means to attack the heavily armored areas of a tank. Improvements to both type of rounds will be realized as increased gun size increases the velocities of rounds and the size of projectiles. Increased size, coupled with improved propellants and combustable or semi-combustable cartridge cases, will serve to maintain ammunition lethality. The tank fire control system composed of optics, elec-

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[28]Woznik: 11

tronics and optronics (combined electro-optical devices) accounts for 50 to 60% of the basic cost of a MBT. What it provides is a high chance for a hit at extreme ranges and 24 hour capability.[29]

Over the last 20 years, developments in laser range-finders, digital ballistic computers and gun stabilization systems have greatly increased the effective range of tank cannons. The laser rangefinder has reduced the error zone for round impact at extreme ranges. The range for an 80% probability for a hit on a conventional tank turret, about four meters wide, has increased from 1500 to 4500 meters. This range increase is due to the ranging accuracy provided by a laser rangefinder. Design of smaller turrets is needed to offset this increased accuracy at greater ranges.

Aiding improved range and accuracy are improvements in zeroing the gun and aligning the line of sight with the projectile's flight path. Zeroing accuracy has been improved with the use of a muzzle reference system, thermal gun jackets to prevent uneven gun heating and cooling, and a standard correction for gun jump.

A major contributor to improved accuracy is the use of digital ballistic computers. These computers, when fed data from the laser rangefinder, muzzle reference system, on-board sensors and the crew, correct a host of error factors. Error factors accounted for are: range, ammunition

[29]Simpkin: 97

nature, superelevation, target azimuth, angle of site, bore wear, gun jump, barometric pressure, ambient temperature, wind velocity, wind direction and batch-to-batch differences in ammunition. The only random variables not considered by the computer are round-to-round variation in ammunition and the differences in wind speed and direction at the firing tank and the target.[30]

Adding to the lethality generated by the factors discussed above has been the development of effective gun stabilization systems. These systems provide a shoot on the move capability by stabilizing the gun and fire control system in both the horizontal and vertical planes.

Besides improving gun accuracy and increasing lethal range, *fire control improvements* have created a dilemma for the tank commander. Assuming the tank commander is responsible for employing his tank in a 150 degree forward arc, increasing effective range from 2000 to 4000 meters has quadrupled his surveillance area. The area to which he and his crew must pay attention has jumped from eight to 32 square kilometers. Future tank design will have to account for this increased area of responsibility. Solutions may lie in providing the tank commander and gunner duplicate target acquisition capabilities. The concern here is to position them or the target acquisition devices high on the tank to reduce vehicle exposure. If the latter course is

[30]Simpkin: 95

chosen, fiber optics may provide the means for remoting crew members from optical devices. An alternative is to provide an automatic target identification and alarm system. Thermal and laser systems offer potential in this role. Whatever the choice, it can be expected that the use of these systems in tank fire control will further increase the system's costs.[31]

The final aspect of lethality is secondary armament. The use of a coaxially mounted machinegun has been constant in historical tank design. The coax machinegun provides a soft target attack capability that is slaved to the main gun and uses the main gun's fire control system. The only deviation in the use of a coax machinegun has been its size. In U.S. tanks of the last 45 years, the coax has ranged in size from the current 7.62mm, to guns as large as 50 caliber.[32] In Abrams development a 40mm grenade launcher and 25mm automatic cannon were considered for the coax role. Although the 25mm cannon was preferred, technical problems in its design resulted in the use of the same 7.62mm as used on the M60 series tanks.[33]

Secondary armament has been provided by the use of a varying number of other machineguns to provide a close-in and anti-aircraft defense capability. A wide range in the

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[31]Simpkin: 95

[32]Hunnicutt, Patton: 422-443

[33]Kelly, King of the Killing Zone (1989): 104, 109

number of these additional weapons has characterized U.S. tanks, from as many as seven additional machineguns in World War II, to the single tank commander's 50 caliber of the M60 family. The effectiveness of these additional weapons in the air defense and close-in role are debated. MG Desobry, Commandant of the Army's Armor School and leader of the initial M1 development effort, acknowledged that a crewman firing one of these machineguns from a moving tank probably couldn't hit what he was aiming at. However, he considered the use of these additional machineguns in a recon by fire role and the morale boost their presence provided the crew, reasons for including both a turret mounted tank commander's and loader's machinegun on the M1.[34]

Secondary armament considerations for future design are size of coax guns and the need for other secondary weapons. An increase in coax weapon caliber may be required to maintain lethality against secondary, non-tank, targets. Consideration for mounting additional weapons should include their battlefield effectiveness versus the trade-off required in complication of the commander's cupola and increased vehicle height that increases probability of exposure.[35]

Tank lethality is a result of the threat and technological capabilities. Threat capabilities will mandate the

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[34]Kelly: 105

[35]Simpkin: 99

requirements for gun caliber, ammunition and secondary armament. Technological capabilities will limit the effectiveness of the fire control system. Future lethality rests on identification and knowledge of the threat and an understanding of technological capability.

COSTS

Simpkin has done an excellent job in identifying the primary considerations of tank design, mobility, protection and firepower. His portrayal of these three design factors by the use of the "marketing mans triangle" provides an easily understandable representation of the complex interrelationships of design. Cost, however, must not be overlooked.

Cost manifests itself in two ways, monetary and personnel. Both provide a restriction on the capabilities of the final product.

Monetary costs accrue from research and development (R & D) costs, production or acquisition costs and operating and sustainment (O & S) costs. The amount of budget authority granted by the Congress limits the first two. Budgetwise, the current era is one of demobilization. This demobilization is a stand down from the military capability that was deemed necessary by the American public in response to the Soviet threat. The generally perceived elimination of this threat and the national budget deficit crisis will combine to significantly reduce defense spending. Cuts of 15-17 billion dollars from the President's proposed Fiscal Year 91 budget are being proposed by Congressional moderates. Even larger reductions are being offered by more radical members.[36] Whatever is the final amount of appropriated dollars, it will portend great impact on military R & D and acquisition programs not only in FY 91, but into the foreseeable future as well.

In a era of austere budgets, equipment O & S costs become crucial. Historically, service life O & S costs for tanks are ten times greater than their acquisition cost.[37] Future design must provide a means to reduce this ratio. The use of technologically advanced components to achieve a reduction in POL usage and improvement in component reliability, availability and maintainability is vital.

Hand in hand with monetary reductions are personnel reductions. No other area provides a more readily visible sign of monetary reduction than does force structure cuts. The Army is planning for a force structure reduction of 184,000 spaces from now until 1997, when a 580,000 man Army is the goal.[38] Future tank design will have to consider ways to mitigate the affects of personnel reductions.

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[36]"Defense Budget is Attacked," The Kansas City Star (April 21, 1990): A-15, a-b.

[37]Koerner and O'Conner: 11

[38]"Army Plans a big reduction in men and armaments by 1997," The Kansas City Star: (April 15, 1990): A-11, a-c.

Maintaining crew size at four in an era of fewer personnel means there will be fewer tanks in the force. Reducing crew size to two or three crew members will allow not only more tanks to be manned, but also will allow a reduction in the size of the tank. Of caution here is that even though crew size has decreased, the range and scope of requirements for the crew, or crew duties, have not changed. The need to replace track, remove engines for servicing and observing the battlefield are some of the duties the crew must perform. Design must consider the use of new technologies to ease the requirements on a smaller crew.

Tank design in an arena of unfettered costs has never been possible. U.S. military and tank design history has been characterized by swings from increased funding during times of heightened world tensions to a paucity of funding following wars. In the current era of Cold War demobilization, significant budget restrictions in both personnel and dollars will be the norm. The challenge for future tank design is to achieve a survivable, mobile, lethal product within the restrictions imposed by reduced budgets.

CONCLUSION

The predominant factor for design consideration which impacted almost all of the others is weight. Weight affects the three realms of mobility, the amount of direct protection that can be achieved and the capability for indirect protection through maneuverability. Lethality considerations of gun size and ammunition also bear on vehicle weight. Vehicle weight is the linchpin around which design must focus.

SUMMARY

This chapter has identified the three characteristics of a tank; mobility, survivability and lethality. Within each of these areas an examination of the technical factors that increase or limit capability for the given area was conducted.

The chapter concluded with a review of the monetary and personnel cost factors which proscribe the bounds within which a tank design must fall. These bounds are becoming more restrictive as defense budgets shrink in response to a perceived reduction in the threat to the U.S. and a domestic budget crisis. The trend for the foreseeable future is for the continued reduction in resources in support of national defense.

CHAPTER 6

ALTERNATIVE TANK DESIGNS

INTRODUCTION

In this chapter the three tank designs to be used in the comparative analysis that follows in Chapter 7 are described. The base case design, the design against which the two future alternative designs are compared, is the M1A1. The first alternative is a conventional turreted design that is in essence an upgraded M1A1. The second alternative is a more radical design, a turretless tank. The examination and identification of tank design considerations conducted in Chapters 3, 4 and 5 are the basis for the construction of these design options.

THE BASE CASE

The base case design used in the analysis is the Army's current main battle tank the M1A1. Even though the M1A1 has been upgraded to the M1A2 model, budget constraints have forced an early termination of the A2 program and less than one hundred of these will be produced. In the absence of large scale production of the A2 model, the A1 will remain the most proliferated, modernized version of the M1 in the Army for the foreseeable future. A quick review of the characteristics of the M1A1 is in order.

The M1A1's main armament is the 120mm Rheinmetal cannon. The cannon fires either chemical energy or kinetic energy rounds. The ammunition is of a fixed single piece design. Forty rounds are carried in a turret bustle stowage area.

The fire control system is composed of a Neodymium: Yttrium Aluminium Garnet (Nd:Yag) laser rangefinder, a digital ballistic computer and thermal sights for the commander and gunner. In addition, a stabilization system provides stabilized operation in the horizontal and vertical planes.

Secondary armament is composed of a 7.62mm coaxial machinegun, 12.7mm (50 caliber) commanders machinegun and a 7.62mm external turret mounted machinegun for the loader. Secondary armament is completed with the use of eight smoke grenade launchers on the turret which can be fired by either the tank commander or gunner.

The M1A1 is armored with composite armor, the composition of which is classified for security purposes. This special armor is estimated to provide protection equivalent to 450mm of conventional rolled homogeneous steel armor.

The vehicle is powered by a 1500 horsepower turbine engine which generates a horsepower to weight ratio of 28 to

1. The M1A1 is almost twelve feet wide, in excess of 25 feet long and about eight feet high.[1]

A TURRETLESS TANK

The generic turretless tank used in this analysis is constructed from the author's interpretation of information presented in previous chapters. Historical U.S. trends in tank design are to improve and upgrade an existing system, using the existing system as a base on which to build. If this holds true, future design will be based on the M1A1.

The first characteristic obviously is that there is no turret. This armored envelope for crew and gun protection has been removed. In its place is mounted an articulated, externally mounted, lightly armored gun.

Removal of the turret decreases total vehicle height. Vehicle height is determined by ground clearance, hull height and turret height requirements. Ground clearance is not changed from that of the M1A1. Hull height is dictated by the height of the engine compartment and the space required for the driver. With the smaller improved propulsion system, some height reduction is achieved. Turret height has been governed by the size of the main gun, main gun depression angle and room for the loader. In the turretless tank the height of the gun and its mount above

[1]Steven J. Zaloga and James W. Loop, Modern American Armor, (1982): 28

the hull is minimal. Achievement of total vehicle height in the 94 inch (7' 9") range of the Soviet T-62 is possible.[2]

The external gun is mounted on a modified M1A1 hull. Modification would result from the need to place one or two crewmen in the hull with the driver. The tank commander and gunner positions are located within the heavily armored front hull. The three crew positions are in a line, abreast of each other. The driver is in the center, the tank commander on his left and the gunner on the driver's right. Additionally, the use of an improved propulsion system decreases the required size of the engine compartment. This is due to an improved propulsion system's ability to maintain current power levels with an engine one-half the size and weight of the current turbine.

With the removal of the turret, the turret ring and basket area is opened for alternative uses. In this design the space is used to provide protected stowage for on-board ammunition.

The elimination of the turret reduces weight by up to one-third.[3] Vehicle weight drops from the 65 ton range[4] of the M1A1 to 44 tons. Additionally, the smaller engine and engine compartment allow even further weight savings.

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[2]Gerald A. Halbert, "Elements of Tank Design." Armor, The Magazine of Mobile Warfare (November-December 1983): 36

[3]Richard Simpkin, "Room at the Top," Armor, The Magazine of Mobile Warfare (January-February 1985): 18

[4]Zaloga and Loop: 28

These savings are offset by some weight growth in the gun and ammunition. The final result could be a tank in the 40-45 ton range.

Light armoring of the gun is required to protect against small arms fire and shrapnel. The gun's caliber is in the range of 140mm, having grown to maintain lethality against advanced armors. Likewise, the ammunition for the main gun has grown in size and weight and the design has resulted in safer two piece ammunition.

To handle the larger ammunition and assist in assembly of it's two pieces, an autoloader has been installed. The autoloader eliminates the need for a crewmember to remain outside the armored hull to load the gun. The use of an autoloader results in the elimination of one crew position. The autoloader aids the relocation of ammunition stores to a low-in-hull position providing increased ammunition protection.

However, there is a disadvantage in the use of an autoloader. Not all of the on-board stowed ammunition is immediately available for access by the autoloader. When the ready rounds in the autoloader have been expended the gun and autoloader combination are required to be moved to a position that allows access to the remaining stores. If the tank is in the middle of an engagement, reorienting the gun to reload could prove devastating. Even with this disadvantage the increased loading speed and ability to safely handle a heavier round of ammunition make the autoloader a valuable asset.

The gun's fire control system has been improved with the use of optronics. Optronics provides an electronic link from the optics to duplicate gunner and tank commander (TC) positions. The fire control optics (sights) are mounted high on the external gun to use the advantage of height to see the battlefield while the crew-in-hull remain masked from view. The Army's current M901 Improved Tow Vehicle is an example of the use of high mounted optics.

The duplicate stations at the gunner and TC positions enable either crewman to employ the tanks weapons systems. The improved fire control system is completed with the use of a target nomination system. This system provides the gunner and TC a heads up display of possible targets, prioritized from most to least dangerous. Slaving the target nomination system to the gun allows for almost instantaneous laying of the gun on the most lethal target, if so desired by the TC.

Secondary armament is composed of a machinegun coaxially mounted with the external gun. The machinegun used is the 25mm Bushmaster automatic cannon. The increased lethality afforded by the Bushmaster and its availability dictate its use. The increased maneuverability and smaller size of the tank eliminate the need for additional armament for the air defense and close-in protection roles.

The Army is presently conducting, or has recently completed comprehensive analyses to determine the best technical approach to pursue in future tank design. The results of these efforts are classified and unavailable to the author. When examined these analytic efforts may disprove some of the author's conclusions about the realm of the possible in turretless tank design. Until such time as those analysis results are available, the design of this turreless tank is based on available open source literature.

From the preceding description the turretless tank would appear to offer advantages over the heavier M1A1. Analysis will prove or disprove this hypothesis. Quantitative analysis of the capability of a turretless tank to satisfy Army requirements when compared to the baseline tank and a conventional turreted design is conducted in Chapter 7.

A TURRETED OPTION

The turretless design described in the preceding paragraphs is a significant departure from conventional turreted tank designs. Past American tank design efforts have been characterized by conservative modifications to an existing design. Even though conservative, these changes have resulted in a more capable tank after application of new components. The alternative choice analyzed here is a less radical change than a turretless effort and more closely follows past U.S. efforts.

The alternative design examined is designated the M1-X. The M1-X, a hypothetical design, is based on the author's interpretation of past trends. Key characteristics of the M1-X are: (1) Same basic hull and turret as the M1A1, (2) Larger main gun, in the 140mm range, (3) The use of an autoloader, (4) the replacement of the turbine engine with an Improved Propulsion System (IPS), and (5) Use of a target nomination system.

This design is based on a historical trend toward increasing main gun size. With the use of a larger gun an autoloader is incorporated to temper the effects of larger and heavier ammunition on the crew. The ammunition, in addition to being bigger, uses improved propellants and is of a two piece design. An IPS, providing equal power in one-half the volume and weight, has been used to replace the turbine engine. Technological advances have led to the incorporation of a target nomination system into the tank's fire control system. The physical dimensions, height, width and weight, of the M1-X are not changed from those of the M1A1.

A summary of the key characteristics of the three tank designs discussed in the preceding paragraphs is provided in the following table:

	M1A1	TLT (est)	M1-X (est)
Main Gun	120mm	140mm	140mm
Scndry Wpns	3 MGs	1 MG	2 MGs
Crew Size	4	3	3
Weight	65 tons	45 tons	65 tons
Height	8 Feet	7.75 Feet	8 Feet
Width	12 Feet	12 Feet	12 Feet
Length	25 Feet	25 Feet	25 Feet
Pwr to Wt	28 to 1	32 to 1	28 to 1

TABLE 6 - 1

SUMMARY

In this chapter the base case design for the analysis is identified. The Army's current MBT, the M1A1, will serve as the analysis base case. Following a discussion of M1A1 characteristics, the alternative designs for analytic comparsion were described. Two designs, based on information provided in earlier chapters, were described. These two designs, a turreted and a turretless tank, provide the second axis of the decision matrices used in the analysis.

CHAPTER 7

ANALYSIS AND DISCUSSION

INTRODUCTION

This chapter begins with a summary of the considerations for future tank design that have been identified in Chapters 3, 4 and 5. This summary sets the stage for an explanation of the analytical methodology used in answering the research question. Then, using the methodology, an evaluation is conducted of the two design alternatives, a turretless tank (TLT) and the M1-X, Insights gained from this analysis are used in Chapter 8 to arrive at the conclusion of this thesis.

SUMMARY OF FINDINGS

Historical

In the review of U.S. tank program history conducted in Chapter 3, three characteristics emerged that carried throughout U.S. tank design efforts. These were: Incorrect/belated identification of the future threat; constraint of peacetime budgets on design, and as a result of this constraint, developmental focus on system components rather than a holistic approach to design. Their repeated occurence, throughout the course of the U.S. tank program, argues that future design efforts should seek to prevent their reappearance. A more complete discussion of these considerations are conducted in the conclusions portion of Chapter 3.

Strategy and Doctrine

In Chapter 4, strategic and doctrinal considerations for future tank design were identified. In the strategic domain, deployability and lethality are crucial design points. The design considerations gleaned from the doctrinal review identified the need for Army materiel to support the battlefield implementation of AirLand Battle doctrine. These three factors are considerations for future U.S. tank design efforts.

Technical Considerations

The last design factors examined were the primary characteristics of a tank and the technical considerations that limit design. In Chapter 5, mobility, survivability and lethality were identified as the principal characteristics of a tank. Armored vehicle mobility is required at three levels; the tactical, operational and strategic levels of war. Nine technical design considerations that affect mobility were discussed. Tank survivability is desired in three realms, direct protection, indirect protection, and crew survivability. Lethality, a tank's ability to kill an enemy, is achieved by a combination of it's main armament (gun), ammunition, fire control system and secondary armament. Of all technical factors reviewed, weight was identified as the linchpin around which tank technical design must focus. Additionally the factor of cost was discussed. For it is cost, the amount of money that can be allotted to tank design, production and sustainment, that ultimately determines design.

The design considerations discussed in the preceding summaries are the elements used in conducting the analysis of the alternative tank design options. Comparison of the capabilities of the two designs in each of the design considerations will provide an answer as to the viability of a turretless design.

ANALYSIS

Methodology

The objective of this analysis is to determine if a turretless tank design is a viable developmental option for the Army. The analytic process used in the evaluation of the two alternative designs is the decision matrix.
The matrices used are designed with the states of nature (things a decision maker cannot change) as columns labeled across the top. The states of nature used are the base case and two tank design alternatives (M1A1, TLT, and M1-X) described in Chapter 6.

The strategies (things the decision maker can change) to pursue are rows labeled top to bottom. The strategies are the twenty three design considerations identified in Chapters 3, 4 and 5. These considerations are: (1) Power-to-weight ratio; (2) Ground pressure; (3) Ground clearance; (4) Road movement capability; (5) Transportability (rail/truck); (6) Amphibious (swim) capability; (7) Height; (8) Weight; (9) Width; (10) Direct protection capability; (11) Indirect protection capability; (12) Crew survivability; (13) Gun lethality; (14) Ammunition capability; (15) Fire control system requirements; (16) Secondary armament lethality; (17) R & D costs: (18) Acquisition costs; (19) O & S costs; (20) Personnel costs; (21) Air deployability; (22) Sea deployability; and (23) Reinforces doctrine.

The twenty three strategies are grouped, for analysis, into the major categories of: mobility, survivability, lethality, costs, deployability and doctrine. Analysis is conducted by the author's subjective scoring of the states of nature (SON) capabilities in each of the design considerations (strategies). Then, the matrix scores for the alternative designs in each of these categories are brought forward to a master decision matrix for an overarching analysis of the two alternative designs.

The scoring system used is a -2 to +2 scale. 0 on the scale represents no change provided by an alternative design over the capabilities offered by the base tank. +1 indicates an improvement over baseline capabilities. +2 indicates significant improvement over the base tank abilities. Likewise -1 indicates a decrease, and -2 a significant decrease in capability from that of the base tank.

After the total scores for the alternative designs in each of the major categories are added, a second weighted analysis matrix is contructed. Weighting of the major categories is done to emphasize the importance of one over another. Weight factors have been assigned by the author. For example, a weight factor of 3 indicates the strategy to which it is assigned is three times more important than a stratgey with a factor of 1. The sum of each of the strategy rows is multiplied by the weight factor. Then weighted sums are added down SON columns to arrive at a final score. The more positive the score, the greater the capability of that design over that of the M1A1. Conversely, a higher negative score indicates less capability is provided by that design. It should be noted that as these decision matrices measure improvement or decrease in capability of an alternative design from that of the base case design, scores for the base design, the M1A1, will always be 0.

Mobility Analysis

The design considerations used in this subanalysis are: power to weight ratio, ground pressure, ground clearance, road movement, transportability, amphibious capability, height, weight and width. The mobility decision matrix follows:

MOBILITY
DECISION MATRIX ANALYSIS

SON STRATEGY	M1A1	M1-X	TLT
P-T-W	0	0	2
GRND PRES	0	0	2
GRND CLR	0	0	0
RD MVMT	0	0	2
TRANS	0	0	1
AMPHIB	0	0	1
HT	0	0	1
WT	0	0	2
WIDTH	0	0	0
SUM	0	0	11

TABLE 7-1

In mobility considerations the key factor is vehicle weight. The TLT design with a weight of 45 tons increases capability over the M1A1 in seven of the nine design considerations in this category. The M1-X, with a weight virtually the same as the M1A1, achieves no capability increase.

While reducing weight, the maintenance of current engine power levels results in an increased power to weight ratio. The improved power to weight ratio is critical to improving battlefield maneuverability. With better maneuverability the vehicle is able to move quickly from covered position to covered position, minimizing exposure time to enemy observation and fires.

Reduced weight also leads to an improved, lower ground pressure. As the ground pressure exerted by the vehicle drops, the terrian available for vehicle operation increases. Areas of the battlefield that previously were considered NO-GO areas, are now usable for maneuver.

Road movement capability is improved with reduced weight. Restrictions on vehicle road movement are primarily a result of weight limitations on bridges encountered along the route. The reduction of vehicle weight by 20 tons increases the number of bridges that can be crossed and eliminates the requirements for time consuming alternate routes or the use of scarce engineer resources. Road movement is also affected by the reliability of power train components. It can be assumed that with a lower weight the stress on these critical components is reduced, resulting in an increase in the mean time between failure of suspension, drive train and engine components.

In transportability considerations the lower weight of the TLT provides marginal capability improvements. These improvements result indirectly from the lower stress the lighter TLT places on truck and rail assets. The key considerations in transportability are length, height and weight. As both variants are based on the M1A1 hull, little capability improvement is gained in this design consideration.

The TLT also gains minimal capability increase in the height consideration. The TLT is just a few inches shorter than the other two designs. While this helps to lower the vehicle's signature it is a minor capability improvement.

From the preceding discussion it is seen that a reduction in vehicle weight provides capability improvements in several design consideratins. The TLT achieves that reduction while the M1-X does not.

Survivability Analysis

The design factors considered in the category of survivability were: direct protection (armor), indirect protection (avoiding being seen and hit) and crew survivability. The decision matrix appears below:

SURVIVABILITY
DECISION MATRIX ANALYSIS

SON STRATEGY	M1A1	M1-X	TLT
DIRECT	0	0	-1
INDIRECT	0	0	2
CREW SURV	0	1	2
SUM	0	1	3

TABLE 7-2

In survivability design considerations the M1-X shows a slight improvement. This very small gain in capability results from the new ammunition that accompanies the use of the 140mm gun. The two piece ammunition is less susceptible to explosion and fire if the tank is hit. In additon, the replacement of the human loader by the autoloader provides all around safety in handling of the heavier, larger ammunition.

The TLT with the lightly armored external gun and autoloader decreases its direct protection capability. A vulnerability is created that does not appear in the other design alternatives.

The TLT's high marks in the survivability area occur as a result of the mobility enhancements discussed earlier. The increase in battlefield maneuverability that results from an increased power to weight ratio and a lower ground pressure, enables the TLT to avoid being hit. Hit avoidance is achieved not only from enemy tank fires but also from the numerous, but slower time of flight, anti-tank missiles on the battlefield. The TLT provides an important capability increase in this design consideration.

As a benefit of hit avoidance, crew survivability is also improved. If the tank is not being hit, crewmembers are not being killed or wounded. Adding to this benefit is the ability to store on-board ammunition low in the heavily armored hull. A benefit that was realized with removal of the turret basket. These improvements are in addition to the safety aspects of the autoloader and ammunition discussed with the M1-X.

The impacts of weight reduction discussed in the mobility analysis are far reaching and are directly responsible for improvements in indirect protection. With the proliferation of anti-tank weapons on the battlefield and the weight penalties associated with direct protection, indirect protection demands attention in tank design.

Lethality Analysis

The design considerations analyzed in this section are the main gun, ammunition, fire control system and secondary armament of the alternative designs. The lethality decision matrix appears below:

LETHALITY
DECISION MATRIX ANALYSIS

SON STRATEGY	M1A1	M1-X	TLT
GUN	0	1	1
AMMO	0	1	1
FIRE CNTRL	0	1	1
2D ARMAM	0	0	1
SUM	0	3	4

TABLE 7-3

In the lethality category both tank designs offer an improved capability in three of the four design considerations. The use of the 140mm gun and ammunition on both the TLT and M1-X result in a more lethal system that achieves an overmatch capability against evolving threat protection systems. The ammunition which uses improved propellants achieves a potent capability for both kinetic and chemical energy munitions. Incorporating the target nomination system into the fire control systems of both tanks provides better battlefield surveillance and target acquisition capabilities than those available on the M1A1.

The TLT gains a lethality advantage over the M1-X because of its secondary armament. Despite the fact that the TLT only has one secondary weapon compared to the three on the M1-X, the 25mm coaxially mounted cannon provides a marked improvement in secondary lethality. The range of targets against which the coax is lethal has significantly increased with the use of the 25mm. No penalty was given the TLT for the lack of additional weapons found on the M1-X. The questionable effectiveness of these weapons in the air defense and close-in protection roles for which they were originally provided and the indirect protection provided by improved maneuverability obviate their need.

In lethality considerations, the M1-X and TLT have very similiar capabilities. Either design would provide the lethality required on the battlefield.

Cost Analysis

In this analysis four cost considerations are analyzed. R & D costs, acquisition costs, O & S costs and personnel costs are examined in the decision matrix below:

COSTS
DECISION MATRIX ANALYSIS

SON STRATEGY	M1A1	M1-X	TLT
R & D	0	2	-2
ACQUIS	0	2	-2
O & S	0	1	2
PERSONNEL	0	1	1
SUM	0	6	-1

TABLE 7-4

The cost impacts of the M1-X are markedly superior to the TLT. This is a result of the M1-X's capability to make maximum utilization of the current M1A1 system. The R & D and acquistion costs associated with the M1-X are from gun development and integration, ammunition development, fire control upgrade with the target nomination system and the improved propulsion system. Additionally, these efforts benefit from existing development programs.

Conversely the TLT is almost a totally new R & D and acquisition effort. Some mitigation of cost is achieved by satelliting off the efforts mentioned above. However, the development, integration and acquisition of the optronics involved in the fire control system, external gun and autoloader systems and required extensive modifications to the M1A1 hull will prove to be costly.

The TLT offers an advantage in only one design consideration, albeit an important one, reduced O & S costs. The reduced costs to operate and maintain the system throughout its service life is significant. Reduction in O & S is achieved through a reduction in required logistics support, i.e. fuel, parts, maintenance, etc. Reduced logistics requirements are the result of the the improved reliability, availability and maintainability the reduction in weight provides. Less weight equals less stress on the systems components. And just as the M1-X achieves savings with the use of the improved propulsion system and reduced crew size, so does the TLT. An additional benefit in O & S cost avoidance is the possibility for commonality. The TLT, a new effort, could be the lead horse for developing a family of vehicles, all based on the same basic design. The efficincies that could be gained from common components, parts, etc offers potentially significant benefit to the Army.

When costs are considered, designers and decision makers must look beyond the immediate cost impacts of a design to what benefits it can provide throughout its 20 - 30 year service life. While the M1-X offers upfront cost avoidance, the total life cycle savings offered by the TLT may provide signifcant cost avoidance into the first decades of the 21st Century.

Deployability Analysis

The two considerations evaluated in this analysis are improved capabilities for air and sea movement.

DEPLOYABILITY
DECISION MATRIX ANALYSIS

SON STRATEGY	M1A1	M1-X	TLT
AIR	0	0	2
SEA	0	0	1
SUM	0	0	3

TABLE 7-5

The critical factors in the air and sea deployability design considerations are vehicle weight and ground pressure. The physical dimensions of the vehicle (height, width, length) also impact, but it is almost always weight which is the show stopper when evaluating air and sea lift capability. The M1-X with a weight equal to that of the M1A1 offers no improvement in capability for these design considerations. It remains limited by the air transport that can move it. The Air Force's C5 Galaxy is the largest U.S. cargo aircraft, but it is also the fewest in the inventory. A tank unit equipped with the M1-X is not rapidly deployable.

The TLT at 45 tons offers advantages for both air and sea considerations. For air transport the ability to fit two TLTs on one C5 sortie becomes a possiblity. Half the number of sorties would be required to move a TLT equipped unit. In the consideration of sea transport the TLTs lower ground pressure provides a capability for off loading on unimproved beaches. Fewer improved beaches or harbor facilities are required than for the M1-X.

In deployability design considerations, the TLT offers considerable advantage over that provided by the M1-X. If the U.S. is to remain a viable actor on the world stage, then the equipment of its armed forces must possess the capability for rapid deployment. The TLT provides that improved capability.

The preceding sections provided an analysis of the capabilities of the alternative tank design options in five of the six design consideration categories. In the following sections, the sixth factor will be introduced.

Integrated Analysis

The goal of this section of the analytic effort is to provide a comprehensive, overarching analysis of the design alternatives. The sums from each of the preceding matrices for both designs are brought forward and applied to the decision matrix at Table 7-6. The sum of the raw scores should begin to provide an inital comparsion of the two designs across all design considerations. The sixth and final design consideration is the capability to reinforce the application of AirLand Battle doctrine. This consideration is introduced in this matrix.

MASTER
DECISION MATRIX ANALYSIS

SON STRATEGY	M1A1	M1-X	TLT
MOBILITY	0	0	11
SURVIVABIL	0	1	3
LETHALITY	0	3	4
COSTS	0	6	-1
DEPLOYABLE	0	0	3
DOCTRINE	0	1	2
SUM	0	11	22

TABLE 7-6

The capability of the two design alternatives to reinforce the application of AirLand Battle doctrine was not examined separately because of its lack of easily definable subcomponents. However, its relative importance to tank design merits evaluation. AirLand Battle is an integrated concept and defies fragmentation. It is the authoritive foundation for developing materiel in the Army. The single piece characteristic of ALB doctrine and its equal importance to the other five major categories justify its evaluation in this section of the analysis.

Both the M1-X and TLT provide an improved capability for the battlefield commander to apply AirLand Battle techniques to combat operations. The larger gun and crew survivability considerations discussed previously reinforce the firepower and force protection aspects of the dynamics of combat power. However, it is the TLT that provides the commander the ability to practice ALB on a higher plane. The TLT provides significantly increased capabilities in mobility, survivability and deployability. These mechanical capabilities translate to improved maneuver and increased physical agility for the force and provides the commander the ability to synchronize his battle throughout the depth of the battlefield. The TLT appears to indeed facilitate the application of AirLand Battle techniques.

When the scores in this integrated matrix are summed the TLT garners a score twice that of the M1-X. In the next section weights have been assigned to each of the six design consideration categories.

Integrated, Weighted Analysis

In this culminating analysis the scores from the integrated matrix scores are multiplied by the author assigned weight factors to arrive at a final basis of comparsion for the two alternative design options. This comparison provides the answer to the research question, the conclusion of this thesis.

MASTER WEIGHTED
DECISION MATRIX ANALYSIS

SON STRATEGY	WT	M1A1	M1-X	TLT
MOBILITY	3	0 (0)	0 (0)	11 (33)
SURVIVABIL	3	0 (0)	1 (3)	3 (9)
LETHALITY	2	0 (0)	3 (6)	4 (8)
COSTS	2	0 (0)	6 (12)	-1 (-2)
DEPLOYABIL	2	0 (0)	0 (0)	3 (6)
DOCTRINE	2	0 (0)	1 (2)	2 (4)
WT'D SUM		0 (0)	11 (23)	22 (58)

TABLE 7-7

The weight factors assigned to the six design consideration categories are the author's assessment of the relative importance of the considerations to one another. Development of the prioritized assessment of these considerations was a result of the author's research effort in support of this thesis.

Mobility is weighted with a "3" to emphasize the across the board impacts that occur from a decreased or increased mobility potential. An increase in mobility, primarily the result of a reduction in vehicle weight, provides increased capabilities in survivability, lethality, costs, deployability and doctrine.

Survivability is also weighted with a "3". The guiding principle in U.S. tank design for the last 25 years has been to ensure the survivability of the crew. The result of this emphasis is the most survivable tank in the world, the M1A1. With the overall capability enchancements that can be achieved with improved mobility, the Army's institutional priority on crew survivability can be extended to the vehicle as well.

The importance of the other four design considerations can not be neglected either. Lethality, doctrine reinforcement, costs and deployability are critical considerations for future tank design as well. The challenge then is to design a tank that enchances capabilities in all six areas of design consideration. A turretless design provides a first step in that direction.

A sensitivity analysis was conducted on the decision matrix at Table 7-7 using the CGSC Military Applications DecMat program. The sensitivity analysis revealed the TLT design as the optimum strategy to pursue and the design considerations were not sensitive to a change in weighting factors.

SUMMARY

In this chapter the analytic effort to provide an answer to the research question was conducted. Two alternative hypothetical tank designs (described in Chapter 6) were evaluated on their potential to provide an increased capability in twenty three areas of design consideration. These twenty three considerations were identified in Chapters 3, 4 and 5. The analysis indicates that one of the alternative designs provides significant across the board capability enhancement. This result is used to support the conclusion reached in Chapter 8.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

The purpose of this chapter is to provide an answer to the research question initially presented in Chapter 1. The focus of all previous chapters has been directed to answering that question. The insights gained from these previous efforts are synthesized by the author to arrive at this thesis' conclusion.

CONCLUSION

The objective of this thesis, the research question to be answered is: Is a turretless tank a viable developmental option for the Army. To accomplish that, four areas to be considered in design were examined: the historical dimension of U.S. tank development, strategic and doctrinal requirements, and technical considerations of design. Identified in the historical examination, conducted in Chapter 3, were three trends that have evolved in the 70 years of the American tank program. These three trends were used to establish requirements for future design.

Chapter 4 identified the requirements the U.S. National Military Strategy and the Army's AirLand Battle doctrine impose on the development of warfighting materiel. Deployability, lethality, and the capabilities of warfighting materiel to allow the battlefield commander to implement ALB doctrine emerged as the key considerations of strategy and doctrine.

The characteristics of tanks and the technical considerations pertinent to all tank designs were reviewed in Chapter 5. Among the eighteen factors discussed, vehicle weight was identified as the most crucial element in tank design.

In Chapter 7, an analysis of two alternative tank designs was conducted. The two alternative designs were constructed from the author's interpretation of the research conducted to support this thesis. These two designs, a turretless tank and a turreted design that is an evolution of the M1, were evaluated on their ability to provide increased capability over that of the Army's current MBT in the twenty three areas of design consideration.

The analysis identified that both alternative designs offered improved capability over the M1A1. The turretless tank design however, provided a more significant improvement than the traditional turreted design. This differential in capability enhancement can be traced to vehicle weight reduction that the turretless tank provides.

The conclusion of this thesis is: A turretless tank design is indeed a viable developmental option for the Army. When considered within the context of the current international and domestic political and economic environments, a turretless design demands serious consideration. The advantages it offers are many and the unconventional nature of its design must not inhibit its complete evaluation by the Army.

The Army must maintain a "versatile, lethal and deployable"[1] force for the future. To achieve that force, consideration of the lessons of the past, a realistic appreciation of the current world and domestic environment, and an innovative approach to the development of materiel is required. A turretless tank provides such an approach.

SUGGESTIONS FOR FURTHER RESEARCH

This thesis by no means answers all the questions that are pertinent to the development and fielding of a turretless tank for the Army. The answers to some of these questions are beyond the scope of this paper, while the answers to others are obscured by the enormous change taking place in the world today. In the paragraphs that follow suggestions for future research are provided. It is the author's hope that some aspiring future researcher will

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[1]U.S. Army, A Strategic Force for the 1990s and Beyond (January 1990): 10-17

conduct an investigation into some of the suggested areas and will shed even more light on the usefulness of a turretless tank.

In the strategic arena, the daily changing world situation that has been the norm since the summer of 1989 will continue to challenge the strategic policy makers of the U.S. government. The National Military Strategy (NMS) of deterrence, supported by the three legs of flexible response, coalition warfare and controlling arms has been a key ingredient in bringing about the current flux in international relationships. As the world changes, so must to some degree the NMS. Future researchers will need to assess the impacts of a changing National Military Strategy on the requirements for future Army materiel.

The impacts of development and fielding a turretless tank on the Army's program of Rationalization, Standardization, and Interoperability (RSI) with our allies deserves evaluation. In the past the trend has been to seek RSI whenever possible. As alliances and the relationships within alliances change, the impact on RSI concerns merits consideration.

The U.S. is currently in a very active period of arms control negotiations. Agreements are expected to emerge in the near future from some of these efforts. Assessment of the impacts of these agreements on the development and fielding of Army weapons is an essential task.

The strategic implications of the American domestic scene also provide ground for future research work. The historic American cultural distaste for a large standing military is again rearing its head. Just as massive demobilizations of the military occurred after the World Wars, Korea and Vietnam, so now is a post-Cold War reduction of military forces occurring. The public clamor for reduced military spending is exacerbated by the need to reduce the U.S. government's budget deficit. In the perceived absence of a threat, cutting military forces provides a quick "peace dividend" that can be devoted to debt reduction or expanded domestic programs. The many players in the budget process have their own ideas on where and how much to cut defense spending. Agreement on a budget for Fiscal Year 1991 is far from being achieved and the long range implications for the outyears are hardly known. Once the tumultuous international situation has settled down so will the budget process and firm plans can be made on anticipated spending authority. Assessing the impacts of stable, smaller budgets on the Army and its materiel development programs will provide helpful insights for Army decisionmakers.

A future research effort would be beneficial in determining the impact of AirLand Battle-Future Nonlinear doctrine on the development of materiel. The development of this update of AirLand Battle doctrine is on-going with completion scheduled for the summer of 1990. Once completed, an assessment of its requirements, compared to the requirements of AirLand Battle, will prove useful to the combat and materiel developments communities.

Finally, an evaluation of the impact of reducing tank crew size from four to three crewmembers, or fewer, is necessary. Future research on the capability of smaller crews to effectively operate a modern tank will be helpful in future designs. Division of combat crew duties in the areas of target acquisition, fire control, communications, maintenance and administrative requirements is critical. Evaluation of the capability of a three man crew to meet the battlefields demands in these areas is essential for future design efforts. The goal is to identify crew efficiencies that will allow for design flexibility and deficiencies which will require development of crew aids. For instance the capability of fewer crewmen to perform the physical tasks of maintaining tanks, such as replacing a thrown track, may require developing special tools to aid a two or three man crew to accomplish this task. The ability of a smaller number of crewmen to effectively fight and maintain the very complicated machine that the tank has evolved into, may ultimately determine the viability of a turretless tank.

SUMMARY

The capability enhancement of a turretless design identified in the analysis in Chapter 7, led to the conclusion of this thesis. <u>A turretless tank design is a viable developmental option for the Army</u>.

The chapter concludes with suggestions for further research. Six research ideas are proposed for a future investigator. The answers to these proposed research questions will prove beneficial to the development of the warfighting materiel of the future.

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